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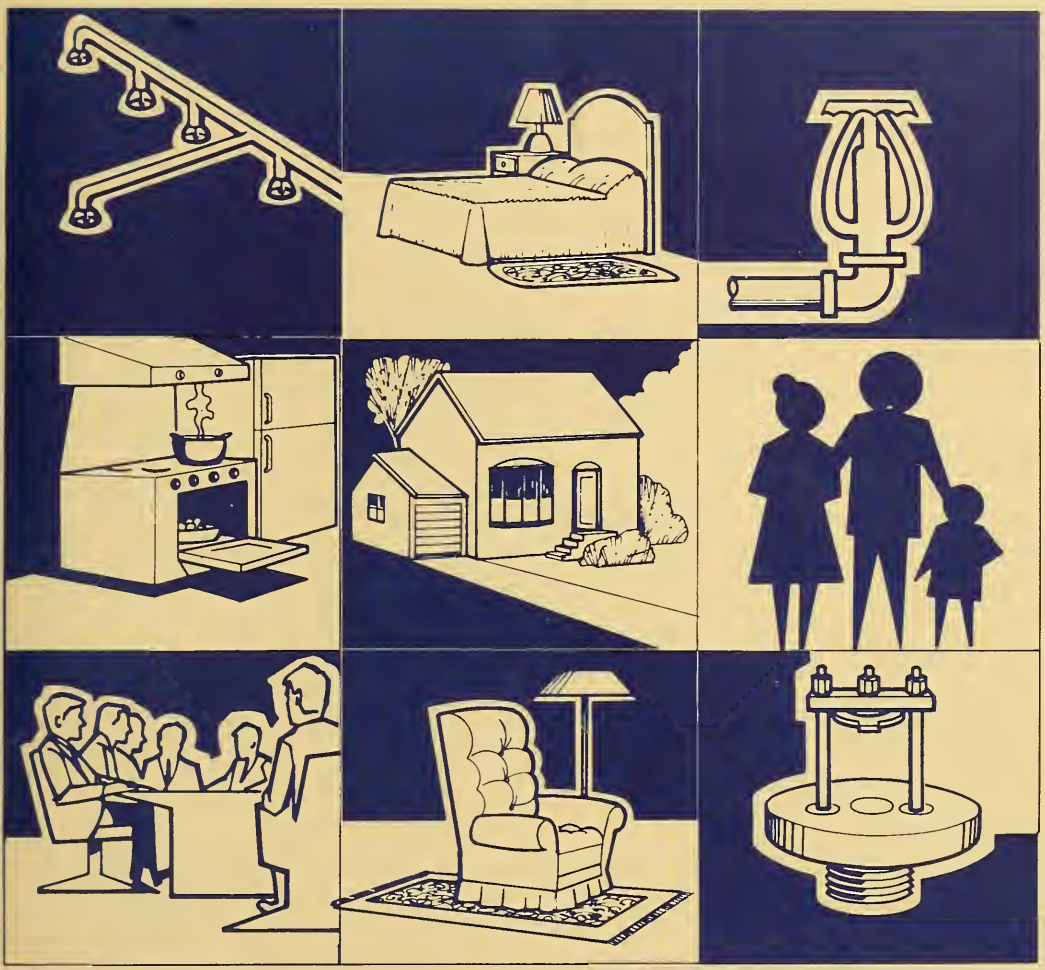

PROCEEDINGS OF THE THIRD CONFERENCE ON LOW-COST RESIDENTIAL SPRINKLERS NOVEMBER 29-30, 1977

federal emergency management agency
U.S. fire administration

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Conducted By:
Federal Emergency Management Agency
United States Fire Administration
National Fire Data Center

Formerly the:
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National Fire Prevention and Control Administration
National Fire Safety and Research Office

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Center for Fire Research

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Johns Hopkins University
Applied Physics Laboratory

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FOREWORD

The Proceedings of the National Fire Prevention and Control Administration's Third Suppression Conference represent the teamwork of at least 50 organizations and hundreds of people dedicating efforts towards reducing fire losses in the Nation.

The Conference goal was to review and evaluate a proposed low-cost residential sprinkler performance standard for use by the NFPA Residential Sprinkler Standard Committee 13-D. I am happy to report the goal was attained.

We are indebted to all who contributed and we now pass the baton to NFPA with our willingness to provide any assistance required to develop a new 13-D Residential Sprinkler Performance Standard.

Joseph E. Clark
Associate Administrator for
Fire Safety and Research

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NFPCA Conference on Low-Cost Residential Sprinkler Systems

Welcoming Statement

Joseph E. Clark
Associate Administrator
National Fire Safety and Research Office
National Fire Prevention and Control Administration

Dr. Berl, it's been a pleasure for us over the years to have had the opportunity to work closely with APL on fire problems. And we'd like to thank you for allowing us to be here to bring this group together to use the facilities.

In many ways, the group that's assembled in this room is truly unique. And I think that the subject of the conference today and tomorrow and what we expect to come out of it will be a unique endeavor in the fire protection field.

Perhaps one of the more noteworthy things from the government side has been the ability of several government agencies to work closely together with a group of grantees, all aimed at the same set of objectives. I particularly want to point out the great cooperation we've had from John Del Gobbo of the National Science Foundation in this regard; the close work and collaboration that we've enjoyed with John has enabled us to pool rather limited resources in fire prevention to accomplish some of the things that we'll be discussing today.

Also, I should mention that even though, bureaucratically, we're both within the Department of Commerce, the close connection with the National Bureau of Standards' Fire Research Center, and the work that John Lyons, Fred Clarke, Dick Custer, John O'Neal and others at NBS have been doing with us is very much appreciated, and I think will be noteworthy during the sessions.

Our Nation's fire problem is not characterized by those tragic, well-publicized but rare fires such as Coconut Grove and Southgate. The recent catastrophic nightclub fire in Southgate, Kentucky resulted in the death of 164 persons. But for years, approximately that same number of people have been dying by ones and twos every two weeks in residential fires!

Look at NFPCA's recent National Estimates of annual U.S. fire losses:

7500 deaths (2/3 residential)

310,000 injuries (well over 1/2 in residences)

$4.2 billion direct property loss (almost 1/2 residential)

Don't these figures justify a concentrated effort to reduce residential fire loss?

Our Residential Technology Program has the aim of reducing the human toll in home fires. Through a systems approach to the problem, we are assessing those technologies that have the greatest potential impact, designing and developing new protective devices and systems, and evaluating existing devices such as smoke detectors.

It is clear that no single approach alone can have sufficient impact on loss. Smoke detectors require proper installation, maintenance and pre-planned human reaction in emergencies. Cases are beginning to accumulate in which one or more of these requirements for human action were not met in a fire emergency. Public education is needed and much is being done by our Public Education Office. Their new series of fire booklets on this subject has been sorely needed.

But smoke detectors and public education need to be supplemented. The technology exists to have smoke detectors also give their alarm directly to the fire department. The two-way cable TV system that does this in Woodlands, Texas is such an innovative system that we are studying it.

Home sprinklers are also emerging as another important weapon in our arsenal. This conference will show you that low-cost sprinkler systems can have great benefits. It is now clear that it is not necessary to flood an entire room to contain a small fire there. About five gallons per minute (or possibly less) is all that is needed to greatly increase time for safe exiting. In addition, the fire department will arrive at a "safer fire".

The presentations today will focus on the technology which exists today that may help solve the residential fire problem. One of the technologies that can have a very significant impact is that of sprinklers. I believe that the performance specification which has been drafted, and which we'll focus on increasingly during the day, and particularly this afternoon, is a primary vehicle for our accomplishing the moving of the sprinklers into the residences.

Gentlemen, I think that you should be fully aware that each and everyone of you are invited here with one particular purpose and one particular reason in mind, and that is that each of you has both a particular role to play, and a particular ability to make it happen. I ask you for your full participation. I'd like full, complete, and open discussion of all the questions, issues and problems that we see going down this road. I would also like to see discussion of whether or not, in fact, you think it's a good road to go down.

If you really don't think that sprinklers are a solution to the residential fire problem, this is the group that ought to bring it out, because that's the track that we're on. We would like to know if there is substantial disagreement with this. Your peer review of the presentations today can make the difference between failure and success in our battle against the biggest fire problem.

Conference on Low-Cost Residential Sprinklers

Harry Shaw
Director, Technology Development
National Fire Safety and Research Office
National Fire Prevention and Control Administration

My presentation today will cover a discussion of the fire problem, the background of NFPCA's R&D suppression role, a review of the NFPCA program for utilizing and improving residential suppression systems, a discussion of the purpose of this meeting and a discussion of where we are going and how we intend to get there.

Dr. Clark mentioned that residential fires were the most significant part of the total fire problem. I would like to elaborate on his comments.

Chart 1 lists all structural fires for 1976. Let us look at the first line which represents dwelling fires. Please take notice that 76% of the civilian deaths, and 29% of firefighter deaths are related to dwelling fires. In the injury columns, 70% of civilian injuries and 49% of firefighter injuries are dwelling related. As far as property loss is concerned, 36% of the dollar losses in structural fires are related to dwellings. As if this were not enough, 50% of all structural fires are dwelling fires. It seems to me that these statistics leave little doubt as to the area in which NFPCA must concentrate to have a significant impact on the reduction of fire losses.

We might first take a minute to examine the history of NFPCA's responsibility for reduction of fire losses. The National Commission on Fire Prevention and Control, which was chaired by Richard Bland, noted in its transmittal letter of its 1973 study, "America Burning":

"... The recommendations emphasized prevention of fire through implementation of local programs in keeping with the very nature of the fire problem which is felt hardest at the community level. Additionally, the recommendations emphasize built-in fire safety, measures which can detect and extinguish fire before it grows large enough to cause a major disaster."

More specifically, "America Burning" has the recommendation that the Fire Administration support the development of the necessary technology for improved automatic extinguishing systems that would find ready acceptance by Americans in all kinds of dwellings.

Another quotation from "America Burning" emphasizes that:

"Automatic extinguishing systems in residences would not only save lives and reduce direct losses from fire, but would also reduce other expenses to the Nation such as the cost of treating burns and smoke injuries, insurance cost and the cost of maintaining fire departments."

"America Burning" played a major role in the development and passage of Public Law 93-498 which established the National Fire Prevention and Control Administration on October 29, 1974. The purpose of the Law was to reduce losses of life and property through better fire prevention and control. Section 8(a) contains the statement - shown in Chart 2 - "The Administrator shall conduct a continuing program of development with the aim of making available improved suppression technology." It is plain that the President and the Congress have issued a mandate to NFPCA

for the development of improved suppression technology. To summarize, the voices of the best and most knowledgeable "fire" brains in the Nation did not only speak, but were heard and they were effective.

Let us now look briefly at the NFPCA residential suppression programs. First, we have a program with the Applied Physics Laboratory/ Johns Hopkins University which is a study of the impact of residential protective devices including suppression systems on the reduction of fire losses where a fire fatality was involved. This study was confined to the State of Maryland and to Washington, D.C. Byron Halpin, APL's principal investigator, will discuss this program. The final report is completed and will be distributed within a week.

The second program is with Rolf Jensen & Associates. This is a study to establish the automatic fire suppression technology for use in residential occupancies. Also included in the study was a considerable amount of work to determine the user requirements of residential suppression systems. Rolf Jensen will discuss this program. The final report has been published and is now in the review process. Hopefully, this report will be available for general distribution in the next 60 days.

The third program is with the Factory Mutual Research Corporation. The purpose of the program was to develop a low-cost automatic residential system. While some work still remains to be done, the completed work contributed significantly to the "Proposed Low-Cost Automatic Residential Performance Standard". Dr. Kung will cover this program in considerable detail. The Factory Mutual final report should be available for general distribution within 60 days.

The fourth suppression program is with the Battelle Memorial Research Institute. This is a program for the evaluation of automatic fire suppression technology and also the development of a low-cost residential sprinkler system. The program was funded through a National Science Foundation grant. NFPCA was appointed technical monitor and David Lucht, the Deputy Administrator of NFPCA, was the Chairman of its Advisory Committee. Norm Henderson will discuss the program findings and conclusions.

The final program is with the Factory Mutual Research Corporation and covers the preparation of a performance standard.

It was our original intent to have the National Bureau of Standards/ Center for Fire Research undertake this program. However, other pressing problems took priority and we were extremely fortunate in being able to obtain Graham Clarke and the Factory Mutual Research Corporation to assume the responsibility for the program.

I would like to say a few words about the performance standard.

We believe that to attempt to develop a 100% effective system, or one that would work in every residential fire situation, would result in an extremely expensive system not affordable by homeowners and, therefore, would not have an impact on the reduction of fire losses. We, therefore, have lowered our sights somewhat and are talking about an 80-85% effective system which would still be able to significantly reduce fire losses. The objectives of the system would be to contain a fire in the room of origin and to create a life-safety environment for some period of time. This would be a significant accomplishment. The development of a system which could contain the fire in the room of origin, where the temperatures are controlled and flash-over is prevented

until the fire services arrive, will be extremely worthwhile. In effect, we have created the "safer fire" Dr. Clark mentioned in his introduction.

The performance standard utilized all of the required data that were supplied from the various programs plus the input from the first and second suppression conferences, and consolidates the material into a single document. This document is just the beginning, not the end. The proposed performance standard will be given to NFPA's 13-D Sprinkler Committee which will be responsible for the next phase in the program. It will be the Committee's job to use whatever parts of the document it feels are applicable. The final standard is the Committee's responsibility. The proposed performance standard that we will forward to the 13-D Committee was Factory Mutual's responsibility. Later on in the program, this proposed standard will be presented by Factory Mutual, discussed by Factory Mutual and defended by Factory Mutual. Ray Praetz will have a team of experts to help him: Gunnar Heskestad, Dr. Kung, Cheng Yao and Graham Clarke. Having read some of the comments, suggestions and criticisms of the proposed standard which came from many of the participants in this session, I suspect Ray will need all the help he can get. I hope that all of you received copies of the proposed standard at least a week ago, and are thoroughly ready to contribute to this meeting by raising questions and making suggestions. As I stated before, we must all recognize that this document is just the beginning.

In order to summarize the program activity, I want to show you a third chart which provides a program overview of what has happened, what is happening, and what will happen.

You will note that impact data were obtained from the APL program and the Rolf Jensen program. Non-technical requirements came from the Rolf Jensen program, Suppression Conference 1 and Suppression Conference 2. The technical requirements came from the two sprinkler studies, one by Factory Mutual and one by Battelle. The outputs of these programs were fed into the performance standard which was prepared by Factory Mutual. Today, we are at Suppression Conference 3. We will review the proposed standard and our comments will be used by Factory Mutual for consideration for possible inclusion in the proposed performance standard. The document will then be given to the NFPA 13-D Committee and to the sprinkler industry. During the period of evaluation by the NFPA 13-D Committee, it is expected that industry will develop experimental systems which we hope will be evaluated as part of our Factory Mutual sprinkler program.

Finally, I want to assure you that when the day comes that the sprinkler industry has a low-cost residential sprinkler system, NFPCA will do its part in promoting that system to the public, to local governments, to the fire services, to builders, and to developers.

Gentlemen, within 60 days we will hopefully officially pass the baton to the NFPA 13-D Sprinkler Committee. We will then become an aide and a friendly critic to do whatever is possible to have a 13-D Standard developed which will have a major impact on the Nation's fire problem. NFPCA has completed its role in completing the first phase of this program. The other phases are: the standards, followed by research and development, and then most importantly, marketing. We have confidence that the

individuals and organizations responsible for each phase will do their jobs. We hope we will be able to continue to participate and contribute in the remaining phases. Now, to get on with the work of the Third Suppression Conference.

Thank you.

Data Not For Release

Types of Fires
Structural

No. of Fires	Type	Dollar Loss	Civilian Deaths	Fire Fighter Deaths	Civilian Injuries	Fire Fighter Injuries	%of Dollar Loss	% of Fires
916,000	Dwellings	1,390,000.000	76%	29%	70%	49%	36%	50%
82,600	Merchantile	444,000.000	1%	10%	3%	9%	12%	4%
634,000	Transportation	494,500.000	10%	___	____	____	13%	34%
65,500	Industry Automobiles Storage	442,000.000	____	11%	3%	11%	11%	3%
51,700	Manufacturing	641,000.000	4%	5%	4%	10%	17%	3%
41,500	Public Assembly	173,700.000	1%	6%	1%	4%	4%	2%
34,300	Education	130,000.000	_____	2%	1%	2%	3%	2%
30,200	Institution	40,100.100	2%	_____	1%	3%	1%	2%
6,500	Utilities, Mines, Defense and Misc.	104,000.000	6%	37%	17%	12%	3%	____
1,859.000		3,859,300.000						

CHART 1

Public Law 93-498
93rd Congress, S. 1769
October 29, 1974

An Act

To reduce losses of life and property, through better fire prevention and control, and for other purposes.

FIRE TECHNOLOGY

Sec. 8.(a) TECHNOLOGY DEVELOPMENT PROGRAM -- The Administrator shall conduct a continuing program of development, testing, and evaluation of equipment for use by the Nation's fire, rescue, and civil defense services, with the aim of making available improved suppression, protective, auxiliary, and warning devices incorporating the latest technology. Attention shall be given to the standardization, compatibility, and interchangeability of such equipment. Such development, testing, and evaluation activities shall include, but need not be limited to . . .

CHART 2

SUMMARY OF NFSRO SPRINKLER PROGRAM

	FY-76/77 Expended	FY-77/78 Programs In Process
I General Program		
APL	63,000	37,000
II Suppression Programs		
Rolf Jensen Associates, Inc.	96,000	
Factory Mutual Research Corp.	79,000	43,000
Battelle Memorial Research Laboratory	[1]250,000	
FM Performance Specs.	10,000	
APL Conference		10,000
III [2]Remote Alarm Systems		
Schirmer Engineering Corp.	———	[2]31,500
	498,000	121,500

[1]$250,000 NSF Grant - NFPCA Technical Monitor
[2] 31,500 Only Sprinkler Related

CHART 3

SUPPRESSION SYSTEMS

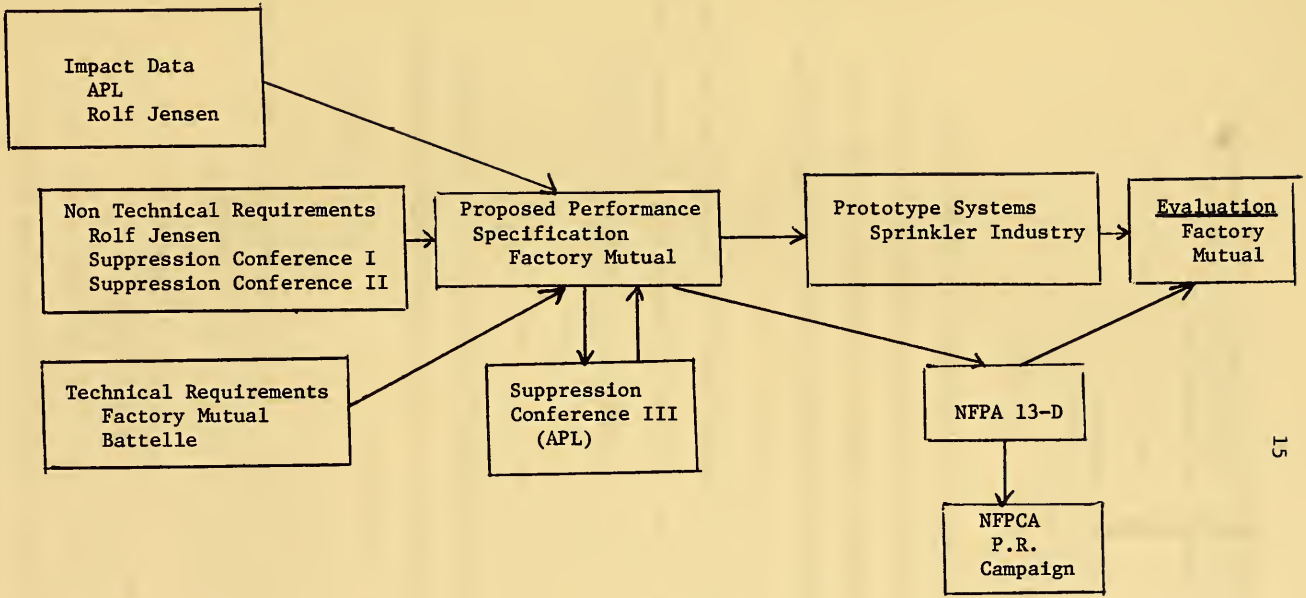


CHART 4

Study to Establish the Existing Automatic Fire Suppression Technology for Use in Residential Occupancies - Findings and Conclusions

by

Rolf Jensen
Peter Yurkonis

Rolf Jensen & Associates

Over the past year, Rolf Jensen & Associates, Inc., along with Schirmer Engineering Corporation, has been conducting a study of the existing automatic residential suppression system technology under contract to the National Fire Prevention and Control Administration.

The ability of an adequate suppression system to cope with extinguishing a residential fire was obvious. The real problems were to identify what was adequate and how we could get adequate systems into the Nation's homes.

Our primary objective was to determine the extent to which automatic residential suppression systems, as they presently exist, can contribute to lowering residential fire losses.

Our second objective was to establish what improvements could be made to increase the practical acceptance and use of such systems.

We approached the project in the following manner:

- An analysis was made of known fire records, losses and research information to establish basic system design criteria such as density, flow rate, and so forth.

- The character of existing technology was identified -- including available agents, piping methods, discharge devices, detection, and so forth.
- Candidate systems were chosen for evaluation.
- The factors which might influence a homeowner to install a system were evaluated.
- The factors which would cause various people to accept, sell, legislate, or otherwise influence the cost of practical basis of acceptance were evaluated.
- Probable successful systems were selected and evaluated for impact, i.e., acceptance and loss reduction ability.
- Possible new approaches to improve acceptance or usefulness were identified.

RESIDENTIAL FIRE

The residential fire scenario was determined by analysis of available fire records and fire research literature. Such factors as origin of fire, ignition source, time of fire occurrence, fuel array, fire growth, and suppression flow rates were established.

CANDIDATE SYSTEMS

Performance criteria for candidate residential fire suppression systems were established based on this characterization of residential fire and:

- Suppression system performance records
- NFPA standards on various systems

Agent systems considered were:

- Water
- Halon
- Multipurpose dry chemical
- Carbon dioxide
- High expansion foam

These were evaluated by use of a logic tree dealing with system design, side effects and cost.

All agents, except water, were excluded from further consideration by this analysis because of a combination of factors including:

- Cost
- Agent toxicity
- Agent-induced damage
- Installation practicality/Agent leakage
- Aesthetics
- Maintenance
- False activation

For example:

- Halon, carbon dioxide, high expansion foam and dry chemical systems are all too expensive.
- Carbon dioxide systems produce a lethal atmosphere at an effective extinguishing concentration.
- Dry chemical and high expansion foam systems cause considerable damage when they operate.
- Total flooding halon and carbon dioxide systems require a reasonably tight enclosure to be effective. Leakage from open windows, doors or attic vents could be excessive.

- The four candidate systems all require special efforts to make them aesthetically acceptable to the homeowner.
- The four candidate systems are all too susceptible to false actuation.

SYSTEM ACCEPTANCE

Factors affecting consumer acceptance of residential fire suppression systems were then investigated by considering:

- Installation cost
- System cost/benefit relationships
- Maintenance requirements
- System aesthetics
- Consumer perception of fire risk
- Other influences

Interviews of potential suppression system users, including homeowners and apartment dwellers in urban, suburban and rural areas, were conducted. The response was surprising. Approximately 50% indicated that they would accept a residential suppression system; 10% rejected systems because of appearance, 10% because of fear of accidental discharge, while 30% of those interviewed indicated that they thought their risk of fire did not warrant the installation of a system. We have a feeling that had we conducted these interviews two years earlier, very few people would have been willing to accept a system, and a far greater number would have considered their risk of fire to be minimal. The recent saturation advertising campaign of the fire detector industry has made the public more aware of fire.

We also talked to others who will influence use of systems including:

- Real estate agents
- Home financing institutions
- Residential fire insurance companies
- Residential builders/developers/designers
- Piping system contractors
- Piping system trade unions
- Suppression system component manufacturers

We found that:

- The sale price of a home could increase, to a maximum of about 1%, if a system is installed.
- Lenders would consider a system desirable and might nominally reduce the mortgage interest rate for a system-equipped home.
- A nominal homeowner's insurance premium credit of 5-10% would be available for system-equipped homes. That credit could increase to 25% if loss experience was favorable.
- Home builders see systems as a selling point and would provide them as an optional item.
- A whole new residential suppression system industry will develop when the demand for systems materializes. New manufacturing processes, distribution methods and installation companies will develop to meet the demand.

We also talked to local regulatory agencies, including health, water, fire and building departments.

These regulatory agencies would:

- Require backflow preventors and meters
- Require plans by a contractor or engineer
- Discourage do-it-yourself systems
- Discourage direct alarms to the fire department
- Consider building code alternatives/density of land use increases and side yard reductions when systems are used.

Having accumulated our data base in the areas previously described, we constructed two logic trees -- one to assess system impact in reducing property damage and one to assess system impact in reducing injuries and saving lives. We also prepared input curves describing event probabilities so an assessment could be made on how each element impacted on the desired goal. Obviously our results are shaded somewhat by the quality of the input data, but we beileve the methods used and the data base are at least sufficient to allow identification of the important elements which will determine whether suppression systems can be a solution to the residential fire problem.

While the logic trees were developed for the purpose of evaluating the impact of automatic fire suppression systems on the national residential fire loss, we feel they can be expanded to become an effective tool in analyzing the total residential fire problem.

In our study we assumed a level for manual fire suppression, construction-restrained fire, fuel-restrained fire and frequency of fire occurrence based upon available fire records. We then held those items constant to explore the effect of varying the ability of automatic fire suppression systems.

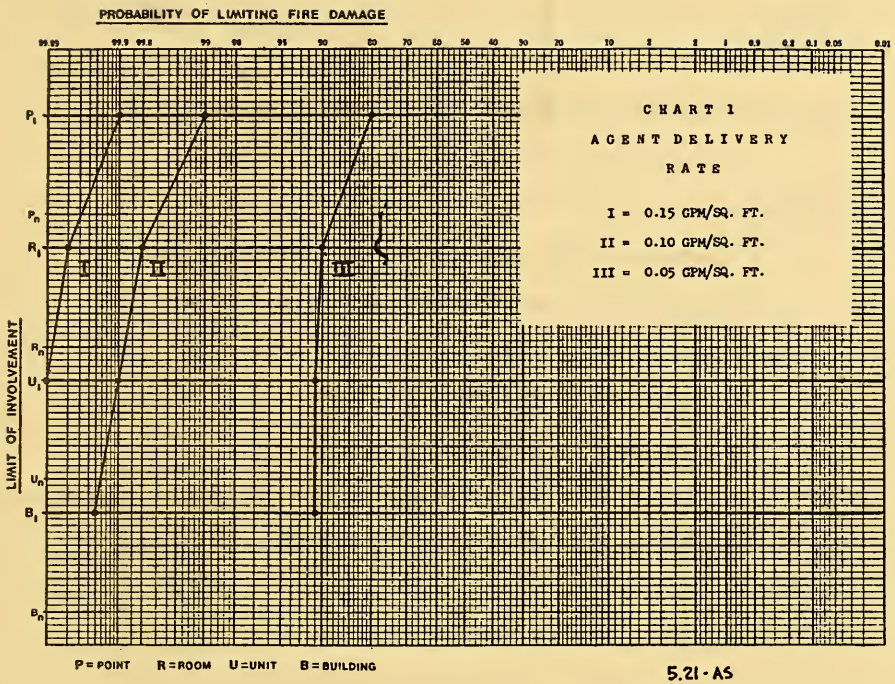
While the precision of this analysis method will continuously be improved as newer fire recording procedures and continuing fire research develop better input data, the method of analysis in its present form is sufficiently precise to be able to evaluate:

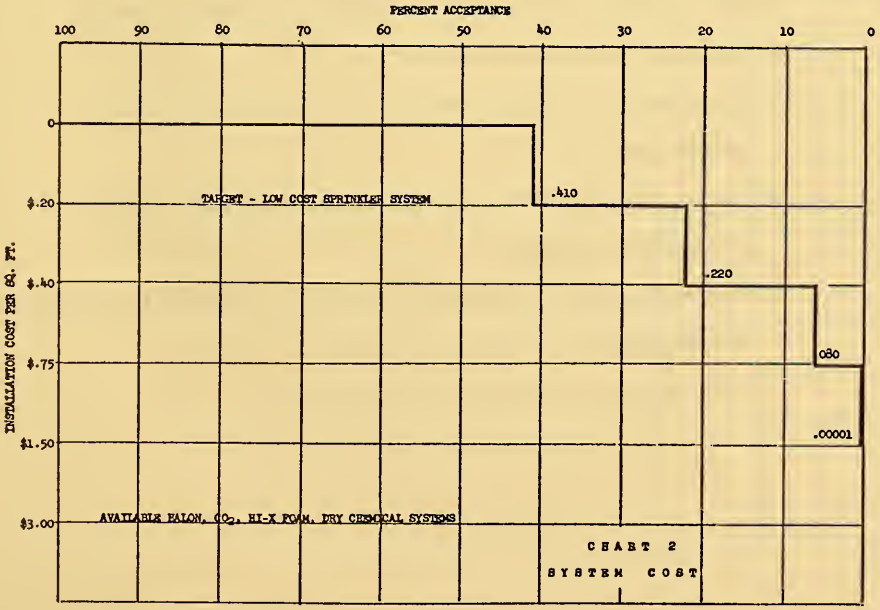
- The approximate impact of systems on the national residential fire loss.
- The relative effectiveness of different types of automatic residential suppression systems.

Well over 140 curves were constructed on charts similar to those illustrations in Charts 1 and 2. These curves (Chart 1 drawn on probability paper) were used to establish the impact of each element on the likelihood of reaching our goal.

Chart 1 shows the effect of varying sprinkler system discharge density. As the density increases, the probability of success also increases.

Chart 2 shows system acceptance expressed by potential users as a function of system cost.


PROBABILITY OF LIMITING FIRE DAMAGE
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.9 0.8 0.1 0.05 0.01
LIMIT OF INVOLVEMENT
P1
Pn
R1
Rn
U1
Un
B1
Bn
I
II
III
CHART 1
AGENT DELIVERY
RATE
I = 0.15 GPM/SQ. FT.
II = 0.10 GPM/SQ. FT.
III = 0.05 GPM/SQ. FT.
P = POINT R = ROOM U = UNIT B = BUILDING
5.21-AS


PERCENT ACCEPTANCE
100 90 80 70 60 50 40 30 20 10 0
INSTALLATION COST PER SQ. FT.
0
$.20
$.40
$.75
$1.50
$3.00
TARGET - LOW COST SPRINKLER SYSTEM
.410
.220
080
.00001
AVAILABLE HALON, CO2, HI-X FOAM, DRY CHEMICAL SYSTEMS
CHART 2
SYSTEM COST

FINDINGS

An inexpensive water suppression system can substantially reduce our national residential fire loss; probably by more than 50%.

The system needs to be:

- Effective in limiting both fire and system-induced damage
- Operable when called upon to react to fire
- Accepted by the public
- Available at a net zero cost

In order to develop such an inexpensive system, we need to reduce the system installation cost and to increase the benefits of installing a system.

Some of the ways system installation cost can be reduced are:

- Increasing the system effectiveness, thereby decreasing required system water supply
- Eliminating the requirements for backflow preventors and meters
- Developing flexible piping to reduce the labor needed to install a system
- Developing system components designed for use in residential occupancies

The benefits of installing a system can be increased in several ways:

- When systems are used, the density of land use may be increased and the lot line separations reduced in recognition of the value of the system protection. Doing this may decrease the unit cost for land, frontage, and common services. Frontage costs include such items as streets, sewers, sidewalks, and utilities. The common services include such items as police protection, fire protection and schools. If the builder can decrease his unit cost for these items by using suppression systems, the real cost of the system will decrease.
- Alternative construction methods may be provided by the building codes when automatic suppression systems are used. Alternatives could involve structural fire resistance, compartmentation, height and area restrictions, emergency exiting requirements, smoke control systems, and first aid fire protection equipment. Again, if the cost of building a residence can be reduced through alternative construction methods, the real cost of a system will decrease.
- System benefits can also be increased through fire insurance premium credits, tax incentives such as a real estate tax credit or a federal income tax credit, or through a reduced mortgage interest rate.

When new suppression and detection systems are developed in the response to the need for a low-cost residential system, there should be a basis for evaluating those systems. A standardized residential fire test procedure is needed. That procedure should be representative of real residential fire conditions and should form the basis for evaluating systems and system components. The procedure is also needed to provide a common basis for comparing the residential fire investigation work now in process and planned for the future and to provide assurance that the systems and components which are offered to the public are indeed adequate to meet the needs of residential fire.

We, as knowledgeable fire protection engineers, have a responsibility to the public to provide them with adequate and reliable systems. That responsibility must be foremost in our minds as we strive to reduce the cost of systems. We must be very careful not to compromise system effectiveness unless we have clearly identified that compromise in a manner which the public can understand. We can be certain that the first failures of residential suppression systems will gain widespread attention and may adversely affect future use of systems.

Residential sprinkler systems as we know them today (i.e., NFPA 13-D systems) may be used in a cost effective manner in:

- Newly developed residential areas provided local zoning ordinances permit increased density of land use and reduced lot line separations when residences are sprinklered. This can reduce the per-unit

cost for land, common services (streets, sewers, sidewalks, police, fire, schools) and utilities which may more than offset the cost of the sprinkler system.

- Multiple family residences if building code alternatives and/or zoning ordinance alternatives are available which permit the builder cost savings in other areas great enough to offset the cost of the sprinkler system.

Generally speaking, sprinkler systems will not be eonomically feasible in new single family residences because the cost/benefit relationship between sprinklers and reduced construction costs or reduced fire losses do not justify the cost of sprinklers as we know them today. However, if we can develop a low-cost sprinkler system using either a packaged water supply or a small volume water supply which can be installed at a much lower cost than a 13-D system, it may well have use in the new single family housing market.

Sprinkler systems will not be used widely in existing construction until we develop a system which is self-contained; one that can be installed as easily as a picture can be hung on a wall. Until such a system is developed, the Nation's existing residential units will not be provided with automatic fire suppression systems, except by legislative action.

Our study did not encompass:

- Fire prevention activities
- The effects of fire resistant construction methods or materials

- The effects of varying the combustibility of the fuel array within a residence
- The effect of improved manual fire fighting response or improved fire detection
- The effect of varying the susceptibility of people to fire injury

The total solution to the residential fire problem must consider all these fa tors. The problem is complex but capable of being analyzed and solved.

As you can see, the bottom line of this whole study is: Yes, it can be done! There are some real practical problems. There are some real consumer acceptance problems. There are some real cost problems. And cost, cost, cost is the biggest emphasis I can give on the whole thing.

But there's a hell of an opportunity out there for the sprinkler industry if they want to go after it.

Thank you.

MR. JENSEN: Do you want to ask questions?

MR. H. SHAW: Rolf, you mentioned zero costs to 20 cents a square foot for systems. Are you talking about today's environment, or do you feel that that would be true five or 10 years from today?

MR. JENSEN: I have no idea what will happen five or 10 years from today. Our studies obviously are based on present day knowledge. For example, we state in the report that if we'd taken the user survey information two years earlier, before the concentrated smoke detector advertising

on radio and TV that's been going on, we would have gotten a different answer. Now, in a similar way, I have a gut feeling that if we took the survey again next year and said, are you guys concerned about fire, that we might change that 50-50 split.

MR. PIETRZAK: Could you comment on the numbers of individuals that you surveyed and do you feel that they were representative?

MR. JENSEN: The organization which actually did the survey for us was a company that does professional telephone surveys. Now, as I recall, the total number was about 700, and then probably another 50 or so in the related interest groups. There were about 700 owners or tenants who represented a whole array of different types of owner-tenant relationships, innercity, suburbs, tenants, multi-family housing, farm properties, as well as housing cost factors. The maximum in any category was about nine people. We are told by statisticians that we may have a 10% order of magnitude accuracy. To go to 3%, one has to go to about 100 in a group, and to go to 1%, one has to go to about 1000 in a group. Now, in data analysis, if you begin to combine groups you can see that the answers begin to push towards that 3% level of accuracy. To go beyond that would take a more extensive study than we were commissioned to do.

MR. O'NEILL: Did you do any cost analysis to obtain possible benefits from reduction in, say, mortgage interest rates? Did you make any assumptions and then develop, say, the 10% with reduction of insurance premiums? Did you develop how low or inexpensive that system must be to end up being at net cost of zero to the customer?

MR. JENSEN: Yes. It's in the report, and it would be impossible, I think, to cover that in detail here. Suffice it to say that for a new building we can do it today, right now, at net zero cost. We don't have to have any new technology. We can do it today.

MR. WERNER: Can you elaborate on that? What assumptions are you making that allow you to say that? That all these items are back-fitted?

MR. JENSEN: If you start adding up benefits derived from -- and this is before the lower potential cost level that could come out of the Factory Mutual work became evident -- I am speaking about cost at about $450 for a $45,000 home. In its consideration, the report adds small bits from mortgage savings, a little bit from insurance, and a little bit on land cost savings; each step along the way adds up and you come out with a net zero.

MR. EARLY: I've heard Dick Patton comment in a similar vein -- that it can be done; the economics are right, in terms of the tradeoff between the benefit and the cost of installing a low-cost sprinkler system. But there seems to be an inconsistency with that type of assessment. I think something you said relating to what the insurance industry is saying that there is only a 5% reduction in insurance premiums or something of that nature. That type of reduction would not cut it in terms of the cost savings.

MR. JENSEN: Not that alone. If you've got an isolated single-family home in a city, you won't cut it. If you're talking about retrofit, you won't cut it. If you're talking about building a new project home in an unincorporated area where you've got the opportunity to negotiate

every possibility with every guy in line, you might make it. That's the place where you can make it at the net zero cost today.

MR. EARLY: But the biggest guy in that chain of events is working with the insurance industry, is he not?

MR. JENSEN: No. It's about 5%. On a homeowner's average premium of $150 you are talking about, say, $7.50 or $10 a year off the insurance bill. That is a small part of the total savings, I'll grant you. But we had some other things in there. We had tax incentives and a whole bunch of other little details like that. But when you add them all up, in the suburban areas, you know, like a planned unit development, you can arrive at it. The real breakthrough, however, is going to come not on the cost basis but on selling the homeowner on the fact that a home sprinkler will save his life. Let's face it, if you can't do it any way other than by freebies, it's going to be a tough, long ballgame.

DR. BERL: How many residential installations are there at the present time?

MR. JENSEN: I don't remember the number right off hand, Walter.

MR. T. SHAW: I compliment you on a very thorough report. I have read it. You keep referring to zero cost, and I can understand your concern with that, of course, trying to make it more attractive to the homeowner. But also, look at the automobile industry. We have to look at the automobile industry and the deaths and injuries that are cost-created there. We now have imposed on us the safety features of the automobile. Certainly, I don't think zero costing was taken into consideration there, and I look at the residential fire segment and I wonder if we really need to zero-cost it. I shall back up this statement. Let me ask as a

consumer and as a potential installer of a sprinkler system in a home that I am in the process of building now, am I talking about $2000, $3000, $4000? One really doesn't know where the cost is going to stop.

MR. JENSEN: How big is your home?

MR. T. SHAW: It will be about 4000 square feet.

MR. JENSEN: About 4000 square feet? You're probably looking at something in the area of $1200 to $1500.

MR. T. SHAW: Right. Which makes it very attractive to me as far as protection of life, safety, and of property. I consider that a very low investment which I anticipate accruing over the years. It will be a tremendous selling feature if I ever sell the home. So, in coming back around to the question of zero-costing, I wonder if we're really not selling ourselves short.

MR. JENSEN: All I'm saying is that for the bulk of the people, our survey shows we will not get to them except on a zero-cost basis, or the alternative is we're going to have to legislate. That's the problem.

Assessment of the Potential Effectiveness of Fire Protection Systems on Real Fire Incidents

by

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I. Nature and Significance of Problem

Most of the fires in the U.S. that result in fatalities and large property damage occur in residences (Refs. 1, 2). Many of the disastrous outcomes can be reduced or eliminated by positive protective programs. One such type of program that should have a significant effect on residential fires is the installation of a fire protection system in residences.

II. Purpose of Investigation

The purpose of this study was to assess the potential value of fire protection systems in the reduction of casualties and property damage in residential fires. Data from investigation of actual fire incidents involving fatalities are analyzed to assess what the potential impact on deaths, injuries and property damage would have been if a fire protection system had been installed in the residence.

III. Investigative Procedures

A. Investigation of Fires

When there is a fire in Maryland or Washington, D.C., in which a death occurs, the Johns Hopkins University, Applied Physics Laboratory investigation team is notified by phone of the incident. At that time pertinent data about the fire are obtained.

The APL team investigates the scene of the fire, usually

accompanied by the fire investigators of the jurisdiction involved. The primary investigators are members of the State Fire Marshal's staff or County or Baltimore City investigation bureaus. The investigation is made to determine such items as ignition source, first item ignited, spread factors, time elements, human involvement, building information, exit capability, and materials involved in the fire. Photographs are taken, interviews are conducted whenever possible, sketches of room arrangements and exit paths in the dwelling are made, and the sequence of events in the fire are recorded by the investigators. The data and information obtained are recorded as part of the case history of the incident to be used later in the analysis and evaluation phase. Data and information of the pathological and toxicological results are obtained from the Medical Examiner's office to include in the overall report and assessment.

A report is written to document the incident.

B. Levels of Protection for Assessment

Three different fire protection systems are considered in this study. The first system is a smoke detector system that passes the UL criteria and is installed according to NFPA standards. The second system is an automatic suppression system with a quick-reaction feature plus an internal alarm capability using water as the agent. The third system is the above smoke detector system provided with remote alarm capability to a fire alarm center.

Some of the important features of each system are summarized below:

1. With the detector-only system, a minimum number of detectors are assumed to be properly installed in accordance with the

guidelines set down in Code NFPA-74-1. The lowest level of protection is provided if one smoke detector is located outside each sleeping area in the residence. In a few cases the manner in which the residence is either constructed or used might cause a variation not necessarily covered in the code. When this occurs, the APL investigators assume the detector location that they believe will provide maximum safety within the basic guidelines of NFPA-74-1.

2. The automatic suppression system is assumed to be designed for residential protection with an audible alarm to alert the occupants. The system is assumed to be installed in the living areas throughout the residence. During the evaluation phase of this study, a further assumption is made that the system is capable of either completely extinguishing the fire or controlling and preventing spread of the fire until the fire department arrives at the scene.

3. Remote-alarm capability in this study has been considered only with the smoke detector system, but that does not preclude the same capability with a suppression system. In this system the fire alarm center is automatically notified as soon as the detector is activated in the residence.

C. Major Assumptions

It is well known that humans can react unpredictably under stress circumstances, including a fire. Many of the people in the cases studied showed signs of being unaware of the magnitude of the fire problem in regard to their safety. Some people question the reliability of an ionization-type smoke detector. Others question whether a sprinkler system will activate before the victims are incapacitated by toxic com-

bustion products. The question of appropriate maintenance of smoke detectors (battery replacement, cleaning, etc.) is also valid.

Considering all possible variations of human behavior in the fire situation and variations in the electronic and mechanical performance of fire protection systems could lead to a different evaluation for each of many scenarios for a particular fire incident. In view of this, it was decided to attempt to determine an "upper bound" to the potential effectiveness of the fire protection system. To do this APL made two basic assumptions in assessing the impact of a fire protection system if it had been installed in the case under consideration:

1. An operable fire protection system is properly installed and maintained.

2. The occupants will react properly to the fire alert, that is, get out of the building and sound the alarm from places outside the burning structure.

The first assumption implies that the fire protection system will alert the occupants before smoke density, toxic gas concentrations, and temperatures reach critical levels for untenability. The second assumption implies that the occupants will react to the alarm immediately and evacuate the building. It is assumed that, once outside, the occupants will send in an alarm to the fire department from the nearest alarm box or telephone, not in the residence on fire. The use of these two assumptions provides a common baseline for evaluating all the fire incidents.

D. Assessing Impact of a Fire Protection System

The initial step in the assessment is to obtain information on the actual losses. The fatality and injury count is normally a simple procedure since fire department investigators routinely log this information in their records. When serious injuries have resulted from the fire, follow-up is necessary to determine whether the injuries led to a delayed death, resulting in more fatalities for the case.

Obtaining estimates of property damage to buildings and contents is more difficult. Some fire investigators are capable of providing a reasonably accurate estimate of the dollar amount of the loss. Other investigators prefer to wait for estimates provided by insurance companies but these data are not readily available. The APL team of investigators also makes an estimate of the actual loss. The loss reported for each case of this study is recorded after a careful evaluation of all sources.

In the APL estimates the location of the residence, the type of construction, the size of the building, and the arrangement of rooms are all considered. The area damaged by the fire is estimated and a replacement cost factor in dollars per square foot is applied to estimate the total fire damage to the building. The cost factor being used ranges from $25 per square foot for simple design houses to $45 per square foot for luxury type homes. In estimating fire damage to contents, current replacement costs for items of comparable quality are used.

Taking into consideration the opinion of state and local fire investigators handling the case regarding the impact a fire protection system would have had in the fire incident, the APL investigators review

the circumstances of each individual case. Major considerations are time estimates for fire spread, fire protection system activation, and reaction of the occupants to the fire danger. After thorough discussion of the possible outcomes in the incident, a consensus judgment is made by the three-member APL investigation team in regard to the impact the fire protection system would have had in the outcome of the fire. The assessment for each system is performed on a mutually exclusive basis, that is, an estimate is made for the fire protection system by itself considering the possible influence that can be introduced by the additive effect of another type of system.

IV. Findings

A. Case Data

During the period June 15, 1976 through June 30, 1977, 71 fatal fires were evaluated for the study. There were 58 fires in Maryland and 13 in the District of Columbia. A total of 231 casualties resulted from those fires, including 112 fatalities. Of the 112 fatalities, 94 were in Maryland and 18 in the District of Columbia. Of the 231 casualties, 42 were firefighters and two of these were fatalities.

The number of fires in which there were survivors totaled 41 in Maryland and 7 in the District of Columbia. Thus, in 66 per cent of the fires at least one person survived or escaped the fire. In a number of the incidents the escapees also aided others to escape.

Data on the source of ignition are obtained from fire investigators from the jurisdiction involved. Their presence at the fire scene affords the best opportunity to accurately determine such data. The

ignition source and room of origin of fatal fires are shown in Tables 1 and 2. Careless use of smoking materials is by far the principal cause of the fatal fires accounting for almost one half of the total. Also noteworthy is the large percentage (over 60 per cent) of the fires caused by human error as indicated by the combined smoking, matches, and cooking categories. The human element, although not always obvious, is also reflected in careless use of flammable liquids and the category labeled "other". The distribution of fires according to cause is consistent with the larger data base obtained in the overall APL Fire Fatality Program (Ref. 3). It should be noted that the distribution of fatal fires according to source of ignition differs from the corresponding distribution for all fires (fatal and non-fatal) primarily in the number of fires in the "smoking" category. Careless use of smoking materials is the source of ignition for half of the fatal fires whereas in all fires no individual source of ignition predominates. Data on the distribution of all fires according to source of ignition is given in Ref. 4.

The distribution of fatal fires according to room of origin is presented in Table 2. The listing reflects the principal cause of fires in that the bedroom and living room are the areas in the residence where careless smoking would most likely occur. In two thirds of the bedroom fires, careless smoking was the suspected cause of the fire. The kitchen is frequently the room of origin in non-fatal fires but much less frequently in fatal fires. The fatal fire originating in the kitchen is usually the result of cooking food left unattended or clothing ignited by the stove.

TABLE 1

DISTRIBUTION OF FIRES ACCORDING TO CAUSE*
STATE OF MARYLAND AND DISTRICT OF COLUMBIA
JUNE 1976 - JUNE 1977

CAUSE	NUMBER OF FIRES
Smoking	34
Matches	5
Flammable Liquids	1
Heating Equipment	10
Electrical	10
Cooking	4
Other	6
Unknown	1
Total	71

* These data are in agreement with the data obtained during the previous 5 years of the JHU/APL Fire Fatality Study. Through correspondence with Mr. J. Ottoson we determined that the data are also in agreement with the NFPCA forthcoming report on National Estimates.

TABLE 2

DISTRIBUTION OF FIRES ACCORDING TO ROOM OF ORIGIN
STATE OF MARYLAND AND DISTRICT OF COLUMBIA
JUNE 1976 - JUNE 1977

ROOM OF ORIGIN	NUMBER OF FIRES
Living Room	23
Bedroom	27
Kitchen	10
Liv-Bedroom*	3
OTHER	8
Total	71

*THIS DESIGNATION REFERS TO EFFICIENCY TYPE APARTMENTS

B. Results and Evaluation

1. Results

The overall results of APL's estimate of the potential impact of three types of fire protection systems on casualties and fire damage in the 71 fires investigated are presented in Tables 3 and 4, respectively.

In the 71 fires investigated there were 112 fatalities, three of the fatalities being firemen. There were 119 persons injured in those fires, including 40 firemen.

The total fire damage was estimated to be $2,128,000 of which $1,649,000 was damage to the building and $479,000 was damage to the contents. The dollar loss includes only estimated property damage and no other economic factors were considered such as hospital costs, time lost from work by the injured, and loss of income by members of the household.

2. Evaluation

(a) Casualties

Based on the assumptions used as guidelines in assessing the potential impact of a fire protection system, 103 of the 112 fatalities could possibly have been saved and 115 of the 119 injuries could possibly have been prevented.

The results indicate that the Suppression System would be most effective in regard to "definite saves" with 97 of the 112 fatalities being saved, compared to 87 saves for the Remote-Alarm Detector System and 79 for the Detector-Only System. If the "probable

Table 3.

APL/JHU

ESTIMATE OF FIRE PROTECTION SYSTEMS' IMPACT ON CASUALTIES
71 Fires with at Least 1 Fatality

(June 15, 1976 - June 30, 1977)

Fire Information				Predicted Results with Installed Fire Protection System		
		Actual		Detector System ①②	Suppression System ①	Remote Alarm System ①③
Casualties	Deaths	112	Saved	79	97	97
			Prob. Saved	20	6	14
			Not Saved	13	9	10
	Injuries	119	Saved	103	114	107
			Prob. Saved	7	1	3
			Not Saved	9	4	9

① Assumes proper occupant reaction and effective system.

② The numbers for the detector system are more "occupant dependant" than the numbers for either the remote alarm system or the suppression system. In addition, detectors must be properly installed, maintained, and tested. Also the occupant must have an escape plan.

③ One death on boat - removed from count since remote alarm system not applicable.

Table 4.

APL/JHU

ESTIMATE OF FIRE PROTECTION SYSTEMS' IMPACT ON PROPERTY LOSS
71 Fires with at Least 1 Fatality

(June 15, 1976 - June 30, 1977)

Fire Information			Predicted Losses with Installed Fire Protection System		
		Actual	Detector System (1) (2) (3)	Suppression System (1)	Remote Alarm System (1)
Property Loss (Thousands) (of Dollars)	Building	1649	524	199	409
	Contents	479	143	73.5	118
	Total	2128	667	272.5	527
	Reduced by		(2) 69%	87%	75%

(1) Assumes proper occupant reaction and effective system.

(2) The numbers shown are based upon the presence of an occupant. Without an occupant the losses will be greater.

(3) The numbers shown for the detector system are more "occupant dependant" than the numbers shown for either the remote alarm system or the suppression system. Detectors must be preperly placed, installed, maintained and tested.

saves" are added to these numbers, the results show that the Suppression System would be somewhat more effective than the other two systems with 103 "possible saves" compared to 101 for the Remote-Alarm System and 99 for the Detector-Only System.

In regard to injuries, the results also indicate that the Suppression System would be somewhat more effective in preventing fire-related injuries with 115 "possible saves" compared to 110 for both the Remote-Alarm System and the Detector-Only System.

(b) Property Damage

The resultant total property damage with a fire protection system installed was estimated to be minimum at $272,000 for the Suppression System compared to $527,000 for the Remote-Alarm System and $667,000 for the Detector-Only System. All of these are significantly below the estimated actual dollar loss of $2,218,000.

References

1. "Fire Deaths in the United States," Fristrom, G., National Fire Prevention and Control Administration, Washington, D.C., Sept. 1977.

2. America Burning: The Report of the National Commission on Fire Prevention and Control, U.S. Government Printing Office, Washington, D.C., 20402.

3. "Fire Problems", Berl, W. G., Fristrom, R. M., Halpin, B. M., APL Technical Digest, V. 14, 2, April-June 1975.

4. Highlights of the National Household Survey, U.S. Department of Commerce, NFPCA.

That concludes what I have to say.

MR. H. SHAW: A comment, not a question. Byron, your numbers are based upon 71 fires. That may not seem like a lot of fires, but the NFPCA has just completed its national estimates, and there's a high degree of correlation between what you have and what is in those national estimates; for example, room of origin. You show something like 73% of the time, room of origin was the living room or bedroom, or a combination living room/bedroom. And it holds up. Second, you show smoking as the source of ignition. If you take the numbers, it may be 30 or 40%.

MR. HALPIN: 50%

MR. H. SHAW: The National Estimates, if you knock out the unknowns, will verify that number as well. So these 71 fires take on a little greater significance.

MR. HALPIN: The other data bases I have, with over 400 fires, correlates extremely well with our data.

MR. STAHL: John Stahl, B.F. Goodrich, representing the Society of Plastics Industry. In your conclusion, you make the assumption that smoke detectors are properly installed. Then can you make a judgment as to the further reduction in life -- in fatalities and further reduction in property damage that would be gained by sprinklers? In other words, it appears that suppression versus detection is about similar, and I think we see a very definite trend towards putting in detectors, which are certainly lower in cost than the sprinkler system. If we'd assume detectors are in, what else are we gaining?

MR. HALPIN: We are trying with our scenario to come up with what we believe is an upper limit or the best condition possible within the fire conditions we have. It is true, each and every one of you can think of a different scenario, or you can sit there and think of multiple sets of fire conditions that would degrade the operation, there's no doubt about it. So what we have done is come up with what we believe is the best these systems could have done under the conditions. Anything else will degrade. I gave some examples of how they were degraded, in fact, within special fires we investigated. But we still find that the suppression systems worked somewhat better than the detection systems.

MR. STAHL: Assuming detectors are installed, how effective are sprinkler systems in addition to that? It appears to me that the effect on life safety may be minimal but the effect on property damage could be significant.

MR. HALPIN: Definitely. You're talking now about combining detector plus sprinkler systems. We must assume that when the sprinkler goes off there is also an alarm that goes off, so in that phase of the detector system the alarm system is there. But we have not assumed a detector, per se, will go off. There will be some conditions where it could go off sooner than the sprinkler system and make the operation more favorable. There will be other situations where the sprinkler and detector will probably go off simultaneously because of the fire conditions. But I believe the combination, definitely, will be much more beneficial to the homeowner, both in life safety and property safety.

MR. CUSTER: Dick Custer, Center for Fire Research. In the slide that you showed with the summary of death and injury impacts in the column

marked "saves", the sprinkler system had more saves than the smoke detection operation. In the "probable saves", the reverse was shown. Can you explain why you get more probable saves with detectors and less with sprinklers when the opposite was true with the confirmed saves?

MR. HALPIN: Primarily because the universe of those that could have been saved was almost the same in both sets. When they added up they came close to being the same. It really was primarily the conditions that occurred when we had more of a flaming operation at the time that the fire seems to occur and when detection could have occurred. So that this trade-off and the fact again that the population of how many could possibly have been saved was almost the same in each situation. The numbers were going to add up to the same total. Which system would react faster and give us more time? Time really is always the element. And that is a difficult part of it, there's no doubt.

MR. CUSTER: If the detectors gave more time for probable saves, why then didn't they give more time for the absolute saves? Or are you including the totally incapacitated in those saves?

MR. HALPIN: Yes. In the saves, there will be some that are, say, partially incapacitated -- maybe they were intoxicated -- maybe they were also healthwise incapacitated, such as invalids. Someone else was in the home and could have made the save. So there are other factors.

MR. T. SHAW: Of the 71 fires studied, where was the breakdown between dwellings, apartments, hotels? Do you have a rough percentage?

MR. HALPIN: I don't have it on the tip of my tongue right now. The majority of them were single-family dwellings.

DR. CLARKE: Fred Clarke, Center for Fire Research. I have a two-part question. First, when you listed the number of dwellings affected by the fire, is that an economic judgment, or is that an estimate of the amount of replacement costs -- zero to 100% -- or is it, say, the amount of wall surface that was touched by fire?

MR. HALPIN: It's the area that was touched by the fire.

DR. CLARKE: It was not an economic judgment?

MR. HALPIN: That's correct.

DR. CLARKE: To follow up, I guess, on what John Stahl was concerned about, is the marginal cost versus the marginal benefit between installing a detector, which I gather was the premise of the detector systems, and the costs of installing the sprinklers, whatever that cost is, the relative benefits you gain going from the detector system to the suppression system; is that right?

MR. STAHL: On one of the charts shown by Mr. Halpin it indicates that detectors would have saved or probably could have saved 99 out of 112 deaths. And then on the sprinklers, the figure was 103. Now that says to me that by having both instead of just the detectors, you would have saved an additional four lives. I'm just wondering if that's significant.

MR. H. SHAW: One of the points that Byron mentioned was the fact that the system had to be in working condition and that the occupants had to react properly. That is especially true with the detector and not nearly as true where there's a suppression system or remote alarm system, because you're going to have third-party help. So in looking at the numbers, the detector number is the highest number you can possibly get, assuming everything works. But we know that the occupants don't do their thing.

We have eight cases out of 71 here. That's 10% right off the bat. So while the number spread isn't too large if one really looks at it and talks about conditions, that spread becomes larger. The saves from detectors go down; the property losses from detectors go up; and there'll be a bigger spread.

MR. STAHL: If I buy that, and if that is the reasonable assumption to make, then I would suggest that maybe that's how we report these comparisons, at least in further documents that will be forthcoming to support the value of the suppression.

MR. HALPIN: Without really good information about the operational characteristics of the systems -- that is, the reliability and maintainability and all those factors -- it's quite difficult to come up with that degradation number. So reading what we did, we did not try to put any kind of bias for any one system versus the other. We just tried to look at it in terms of what could have been the best results that could have been obtained and start getting more data about the various systems so that we'll know how to degrade these systems, and that data base is just not readily available.

MR. KUCHNICKI: Dick Kuchnicki, National Association of Home Builders. Didn't you say that these figures were based, however, on minimum levels of NFPA-74 where the detector would only be in the bedroom area? Do you have a feel at all for how those figures would change if you went according to the new NBS recommendations?

MR. HALPIN: I was asked that question once before. It just happens that we have a lot of cases where we probably would not have had a significant change, primarily because of the heating equipment that was in most of

these homes. We have a lot of central, hot water type systems, not too much of hot or circulating air systems. And we have also had a fair number of single-level instances. So to answer your question, I'd say maybe 10% at the maximum.

MR. DE CICCO: Paul DeCicco of New York Polytech. I'm not sure I understand how you figured the saves with a suppression system of people who would be in the fire room, room of origin.

MR. HALPIN: They're not necessarily all in the room of origin. They could be throughout the building. For those in the room of origin, the question is, have they been touched at all at the time, and what kind of fire did you have? What kind of ignition source did you have? If you have a faster fire, you may not have that really high level of toxic atmosphere. The person may in fact be saved.

MR. DE CICCO: So you made assumptions along these lines that decided how many people would be saved with the timeliness of the sprinkler going on?

MR. HALPIN: Yes. Each event has to be looked at separately from that standpoint. What happens when; where are the people; what kind of reaction could have occurred; do they have an escape route left to them or not? In some cases maybe they don't even have an escape route remaining -- the only way out is through the fire. And when they make that judgment to go through it, some of them won't.

MR. DE CICCO: You had to assume somehow that the sprinkler activating at some time following the incident and so forth -- that must be very hard to do.

MR. HALPIN: Yes.

MR. BRYAN: John Bryan, University of Maryland. Byron, you gave the case of the hotel fire with 70 people saved, three fatalities. What is the total population exposed in these 71 fires? How many people? You had 112 fatalities, 119 injuries. Do you have the number of people exposed in these 71 fires?

MR. HALPIN: Not all of them, John, because there were some cases -- not that one -- we know that in that hotel they were exposed, at least to the smoke. But we have a couple of apartment complexes that emptied out several hundred people. Not all of them were exposed. So getting the actual number of people exposed in some cases was not always possible. We do not have that number included. We have the casualties and the fatalities but not all of those that have been exposed, no.

MR. PATTON: I wonder if there's any way to go back and pull out this data. I think it would be pertinent to the question that John Stahl raised. You are making an assumption that people will react and leave the home the moment the smoke detector sounds an alarm. This is the basis of your figures. But, basically, if we go back and we look at your data realistically of who got killed in the fire, it predominantly seems to be the people who had already been alert to the fire, knew the fire was in progress, got up, and for some reason simply did not leave the home -- either intoxicated, sick, or as you brought out previously, did not comprehend the seriousness of the fire. So the people who died from fire seem to be predominantly those who did not react to the fire when they knew about it and did not leave the home. I am wondering if there is any way to pull this together, to tie the two things together and make an assumption as to how many people might not react to the smoke

detector -- you see, in the one instance, the human has to react to the fire to save himself. In the other instance, the system terminates the fire danger and does it for the individual. I wonder if we could get that into the statistics in any possible way?

MR. HALPIN: I'd need a bigger crystal ball to do that, because you also have to add another factor. A lot of these people do see the fire when it has built up. But this is human detection. It's not detection by a system. If you back off from there and say, okay, the system did detect like it's supposed to, then you have one case. If you started from the point of when they did detect and what they did, that is another phase of the problem. And yes, the majority of the people who died did, in fact, act in a fashion that caused them to be the victims.

DR. BERL: There is one missing link in the data. One does not know at the present time how many people are successfully reacting to fire detectors giving an alarm. All one knows from Byron's data is how many people made mistakes and reacted inappropriately. He does not have any information on how many saves are being made. Until that type of information is available one can't answer Mr. Patton's question. Maybe people will do the right thing with detectors.

Low-Cost Residential Sprinkler Systems

by

H.C. Kung

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I INTRODUCTION

Loss of life and property due to residential fires can be greatly reduced, if a large percentage of residences are equipped with automatic sprinkler systems[1]. However, the current design concept for residential sprinkler systems, resulting from relaxation of the industrial-oriented standards, produces a system still too costly to be widely installed. In order to improve system acceptance, it is vital to develop low-cost reliable residential sprinkler systems.

By utilizing water in a more efficient manner, the required water discharge rate in controlling residential fires can be significantly reduced. Low-cost plumbing and a limited water supply will then be adequate to handle the smaller water demand. Consequently, system costs can be reduced substantially.

A program is underway at Factory Mutual Research Corporation with the objective of developing sprinkler systems which require significantly less water than the current standard[2] (NFPA 13-D), but still provide adequate protection for both life and property.

It is expected that the information gained in this program will lead to new performance criteria for approval and listing by recognized laboratories, and will provide a guide for installation standards and

further development of low-cost residential sprinkler systems.

II METHOD OF APPROACH

The purpose of a residential sprinkler system is twofold: 1) to assure a survivable environment for a certain period of time sufficient to allow occupants inside the fire room to escape or to be rescued, and 2) to protect property. The survivability can be evaluated from the gas temperature and concentration of carbon monoxide at eye level in the room of fire origin. The adequacy of property protection can be determined from the ceiling temperature above the fire source.

Sprinkler performance in residential fires depends not only on sprinkler discharge conditions and the thermal sensitivity of the sprinkler link; additionally, it depends on building geometry, ventilation conditions and fire load. Evaluation of sprinkler performance under various building geometries would be very costly. Therefore, an existing test apartment was selected as the fire test site.

Since the cause of the majority of fatal residential fires has been attributed to "smoking" in a living room or bedroom,[3] all the fire tests conducted for evaluation of sprinkler discharge conditions have been living room fires started with simulated cigarette ignition. The room geometry, ventilation conditions and fire load were maintained constant.

A series of realistic fire tests have been conducted, varying the sprinkler discharge conditions in a systematic manner. In all the fire tests, CO concentration, gas temperatures and ceiling temperatures were monitored continuously for assessing the adequacy of sprinkler protection to life and property.

III EXPERIMENTAL SETUP

3.1 TEST FACILITY AND INSTRUMENTATION

The test structure contains a 741 sq ft apartment area, a 139 sq ft instrument room and a 58 ft long corridor. The layout of the apartment is shown in Figure 1. Two pendent sprinklers were installed at the ceiling in the living room, each covering a 150 sq ft floor area. The distance between the two sprinklers was 12 ft. A flow meter and pressure guages were installed in the sprinkler piping system to measure water discharge rate and water pressure.

Seven geometrically similar sprinklers were fabricated for the program, based on the proportions of a commercial design (see Figure 2). The orifice diameters of these seven sprinklers are 0.438 in. (corresponding to standard, 1/2 in. sprinkler), 0.329 in., 0.274 in., 0.219 in., 0.164 in., 0.137 in., and 0.110 in. The linear-scale ratios, referenced to the largest sprinkler, are 1, 3/4, 5/8, 1/2, 3/8, 5/16, and 1/4.

The experimental sprinkler was activated by a fast response commercial link (located 8 in. from the experimental sprinkler) by means of a solenoid valve. The link has a temperature rating of 165°F and a time constant near 120 sec at 5 ft/sec gas velocity[4]. The sprinkler link sensitivity was maintained constant throughout the program.

The living room in the test structure was instrumented to measure a total of 71 data channels; these include 1) measurements of CO, CO_2 and O_2 concentration at eye level, 2) optical density measurements at eye level and 3 in. beneath the ceiling, 3) three measurements of the gas flow velocity underneath the ceiling, 4) a continuous weight loss measurement of the fuel, and 5) 62 thermocouple measurements.

Of the 62 thermocouples, 42 were employed in 21 pairs to measure

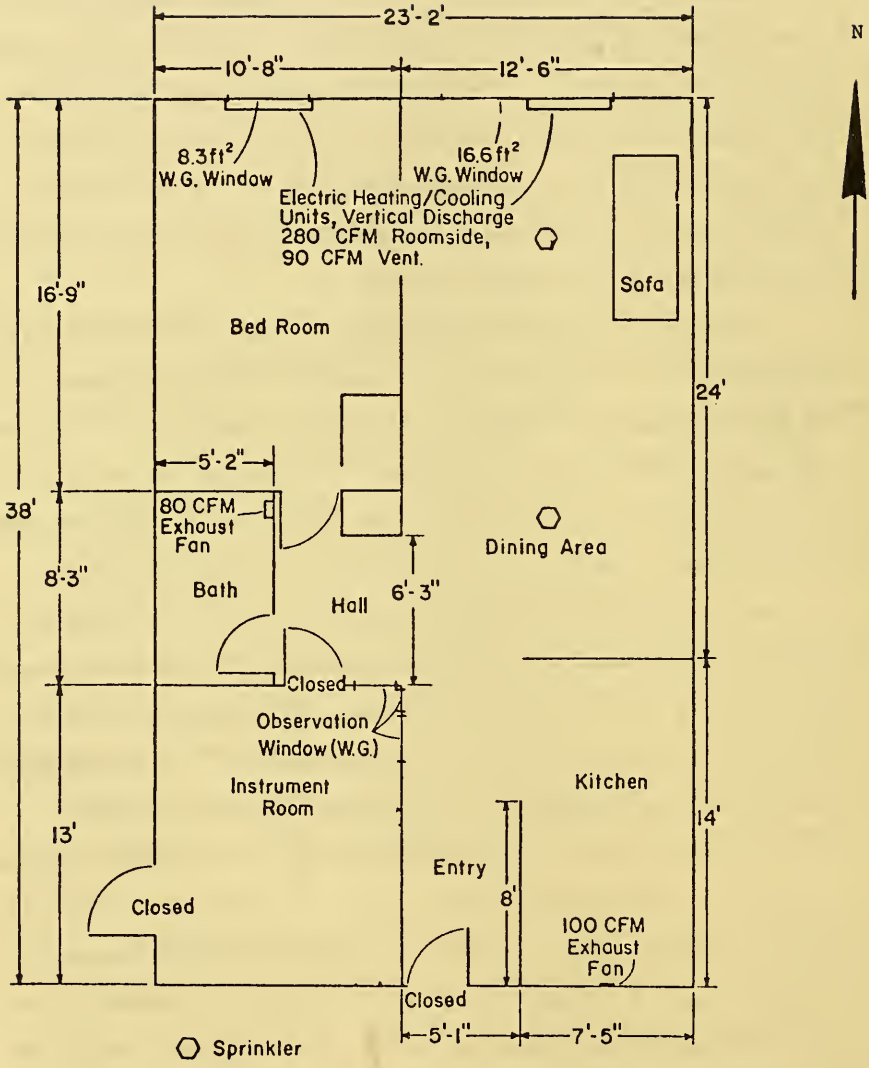

FIGURE 1 TEST APARTMENT FLOOR PLAN

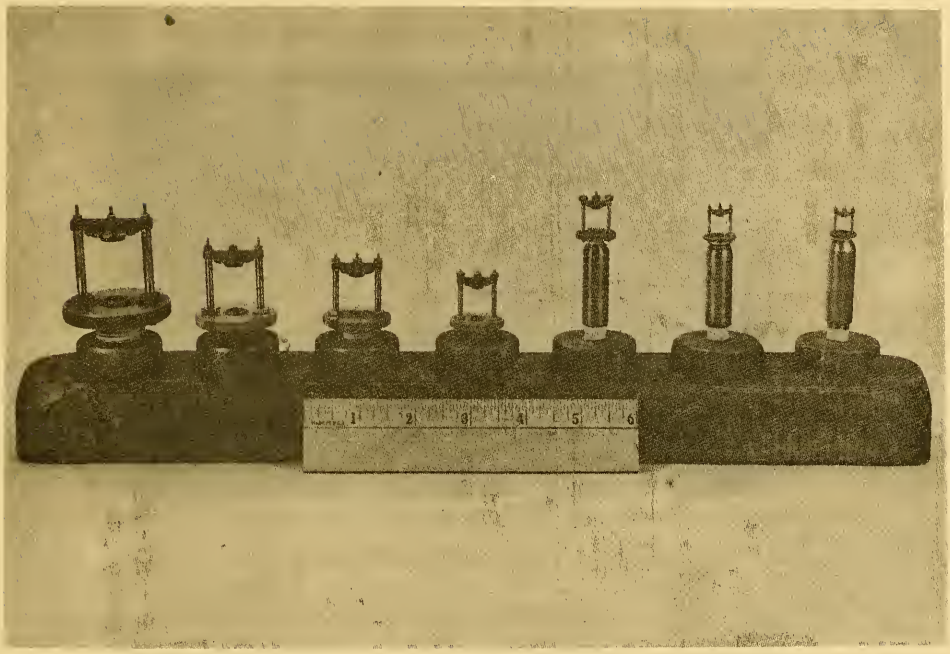

FIGURE 2 THE GEOMETRICALLY SIMILAR SPRINKLERS

FIGURE 5 SOFA LOUNGE AND ROOM DIVIDER

FIGURE 6 SOFA LOUNGE

the outside and inside surface temperatures of the walls and ceiling at strategic positions. The other 20 thermocouples were installed inside the room to measure gas temperatures.

3.2 FURNISHINGS

The apartment was furnished with only a couch and room divider. The couch was of a sofa lounge design (75 in. x 33 in. x 19 in. high), and consisted of a wooden frame with metal springs, a 5 1/2 in. foam mattress, and two (36 in. x 8 in. x 12 in. high) urethane foam bolsters The covering for the frame, mattress, and bolsters was a cotton and linen blend fabric treated with Scotchguard brand fabric protector. The couch was positioned in the northeast corner of the living room, 3 in. from the east wall and 29 in. from the north wall.

The room divider (42 in. x 13 in. x 69 in. high) was positioned 144 in. from the north wall and 24 in. from the east wall. It was constructed of composite board with a walnut veneer. The primary purpose of the divider was to house the light source and power supplies for the optical density meter.

IV EXPERIMENTAL PROCEDURE

4.1 PROCEDURE

During each test, the instrument room and entrance doors were closed as were the doors in the corridor. All the windows were also closed. The doors to the bedroom and bathroom were left open. Air conditioners in the living room and the bedroom were run in the heating mode. Fans in the kitchen and bathroom were turned on.

In Test 1, a lighted cigarette was placed under the front edge of the left bolster, 18 in. from the end of the couch to investigate the development of smoldering fires started by cigarette ignition. The

cigarette was consumed in approximately 40 min. In the first 40-min period very little smoke was generated. However, smoldering had been initiated on the couch. At 109:30 min from ignition, flaming occurred. At 110:30 min, the commercial sprinkler link fused and the test was terminated.

The success of initiating smoldering repeatedly and reproducibly by placing a cigarette on the couch could not be guaranteed. Therefore, for the remainder of the test program, a heating coil* (an immersion heater) was used to simulate cigarette ignition. The coil was spread open to 3 in. and placed at the same location as the cigarette in Test 1. The coil was left in place for 30 min powered at 50 watts, and then removed from the room. Smoldering on the couch continued for approximately 30 more minutes before transition to flaming occurred. The activation time of the sprinkler near the north wall was in the range of 56 to 130 sec. after flaming. The sprinkler near the hall was never activated by fire.

For all the fire tests except Test 1, the sprinkler was operated for at least 20 min. The water discharge rate was maintained constant and sprinkler-discharge pressure was recorded. After 20 min of sprinkler operation, the test was terminated.

4.2 COMPARISON OF THE SMOLDERING FIRES FOR CIGARETTE AND HEATING COIL IGNITION

Figure 3 shows the histories of CO concentrations at eye level for the cigarette-started fire and one of the heating-coil-started fires. For the cigarette-started fire, the abscissa has been shifted 45 min. 19 sec to match the time of sprinkler activation for the two tests.

*A heater of the kind often used to heat the water in a teacup, rated 300 watts at 110 v (KDK, Japan)

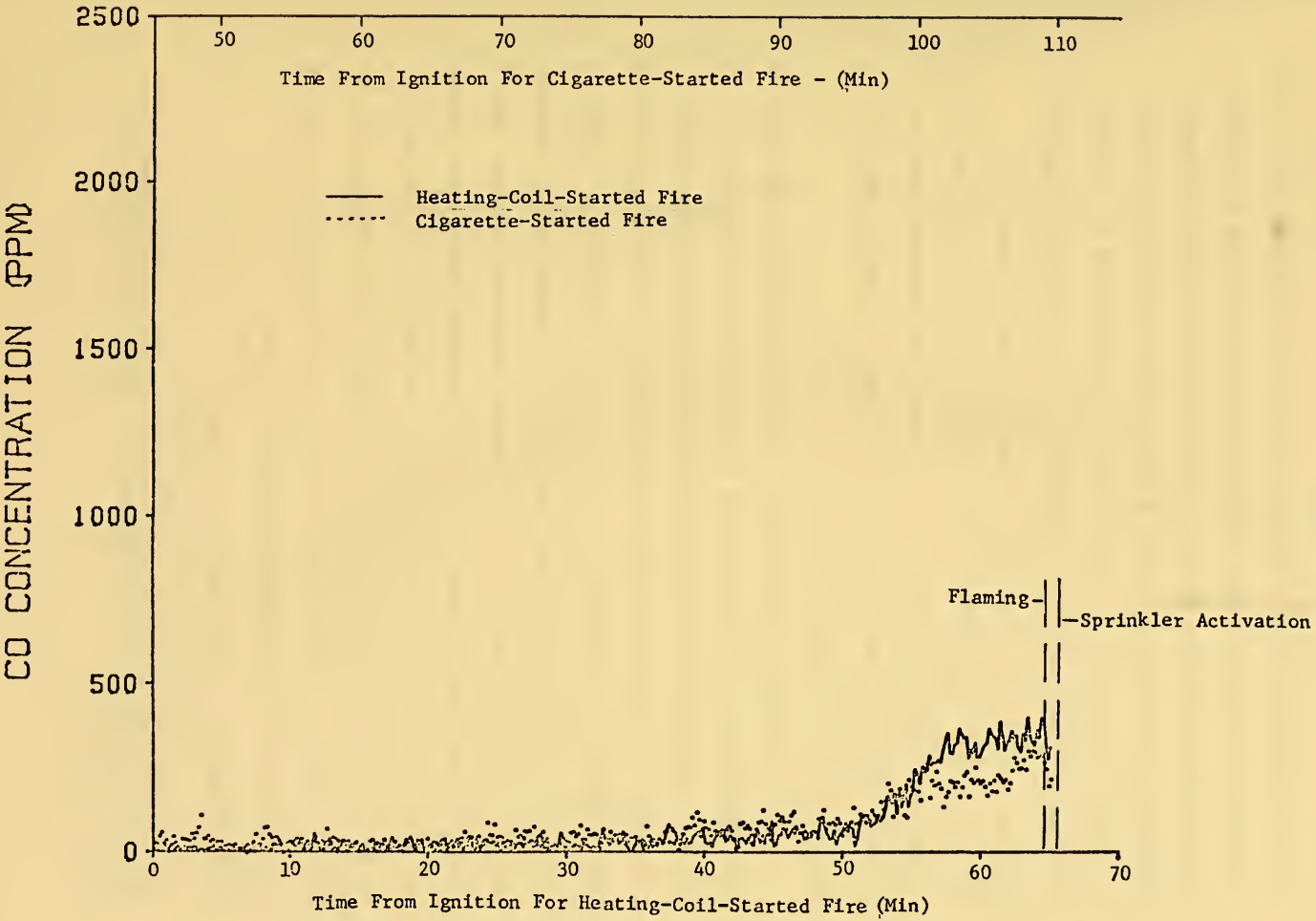

FIGURE 3. COMPARISON OF CO CONCENTRATION AT EYE LEVEL IN LIVING ROOM BEFORE SPRINKLER ACTIVATION FOR CIGARETTE-IGNITION FIRE AND HEATING-COIL-IGNITION FIRE
(Location:62-in.Above Floor, 53 in. From West Wall and 13.33 ft. From North Wall)

(Very little smoke and CO generation occurred in the first 45 min.) For both fires, CO concentrations increased slowly up to 15 min before flaming and then increased at higher rates, reaching 290 (cigarette-started fire) and 310 (heating-coil-started fire) parts per million at flaming.

Figure 4 shows the histories of the optical density* at eye level for these two tests. Again the abscissa for the cigarette-started fire has been shifted. For both tests, the optical density started to increase rapidly approximately 15 min. prior to flaming, reaching 0.26 $ft.^{-1}$ (cigarette-started fire) and 0.44 ft^{-1} (heating-coil-started fire) at flaming. (The range of values of optical density at flaming for all the heating-coil-started fires was .23 - .60 ft^{-1}.)

These comparisons indicate that a reasonable simulation of cigarette ignition can be obtained using a heating coil as the ignition source. The heating coil causes the smoldering fire to become established much more quickly than the cigarette but, once established, both fires follow similar histories. For all tests, the smoldering activity started to increase rapidly approximately 15 min before flaming, increasing very rapidly in the last 5 min. The burn patches on the couch just prior to flaming always formed a 1 1/2-2 ft diameter semicircular pattern on the couch mattress and a 1-1 1/2 ft diameter semicircular pattern on the bolster. Smoke generation in the last minutes before flaming was always vigorous, forming a rising smoke plume extending about 3 ft. above the mattress before dispersing throughout the room.

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*Optical density per unit length is defined as

$$OD\ (ft^{-1}) = \ell^{-1} \log_{10} (I_o/I)$$

where ℓ is the optical path length (ft^{-1}), I_o and I are the photodetector output (linear with light intensity) in absence and presence of smoke, respectively.

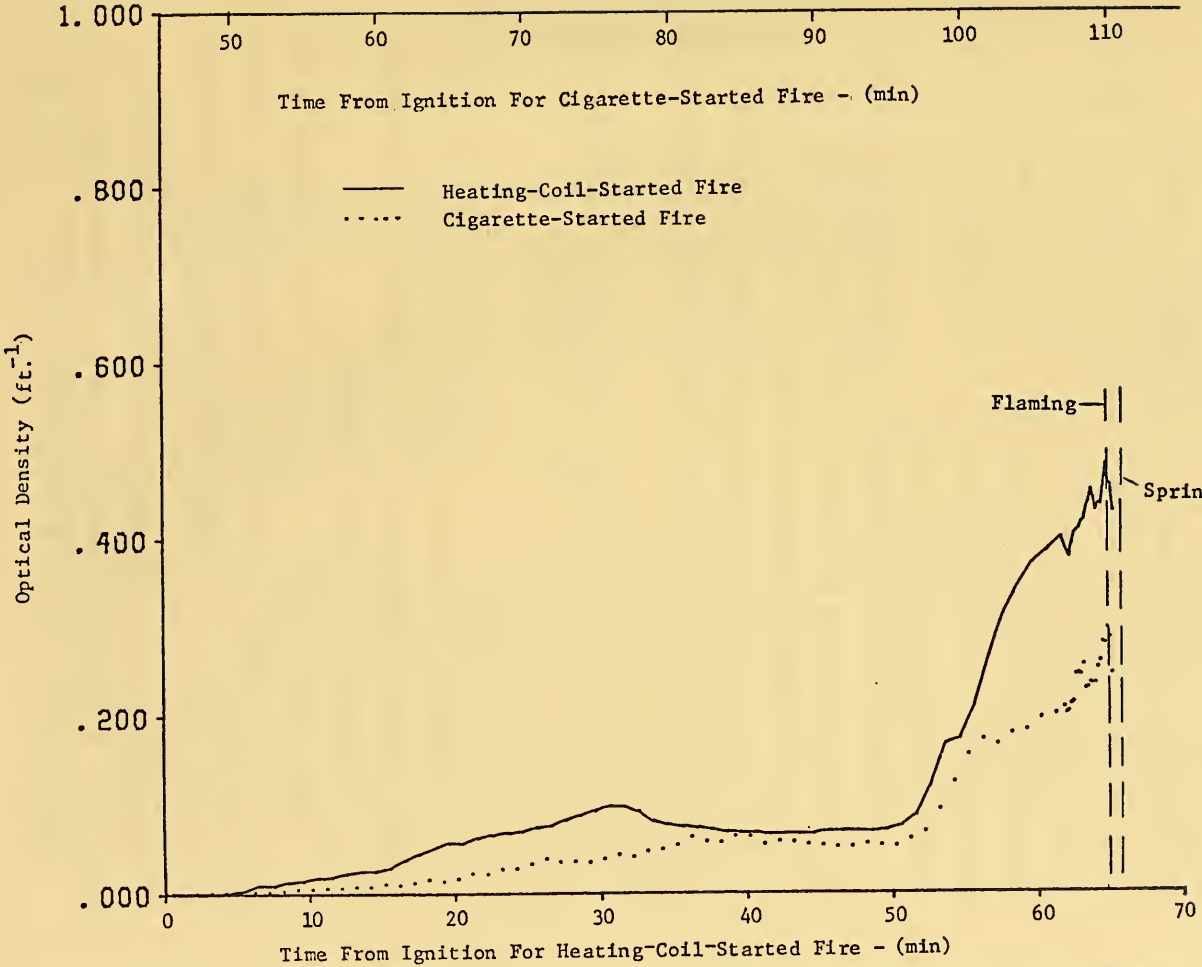

FIGURE 4 COMPARISON OF OPTICAL DENSITY AT EYE LEVEL IN LIVING ROOM BEFORE SPRINKLER ACTIVATION FOR CIGARETTE-IGNITION FIRE AND HEATING-COIL-IGNITION FIRE (Location: 4-ft. Light Beam, 62-in. Above Floor, and 13 ft. From North Wall)

V RESULTS

Three sprinkler-discharge pressures were employed in the test series: 8, 28.5 and 88.5 psig. For each discharge pressure, three different sprinkler sizes were employed, corresponding to three different discharge rates. Table I lists the discharge rate, application density*, K factor** and relative drop size, for the sprinkler discharge conditions tested. The 0.438-in. sprinkler operating at a 0.1 gpm/ft^2 density complies with the NFPA 13-D standard for installation of sprinkler systems in one- and two-family dwellings.

Geometrically similar sprinklers were employed, for which the relative volume median drop size varies as the -1/3 power of the water pressure and 2/3 power of the orifice diameter[5] Hence, the variations in water pressure and sprinkler size correspond to predictable variations in relative drop size. The predicted values of relative drop size are included in the Table.

The approximate local application density over the surface area of the mattress of the couch is also presented in Table I.

5.1 LIFE-SAFETY PROTECTION

The adequacy of life-safety protection provided by sprinklers can best be evaluated from measurements of CO concentration and gas temperature at eye level in the room of fire origin.

Carbon monoxide exerts its primary toxic effect by reducing the oxygen carrying capacity of the blood. Once CO enters the body, it combines reversibly with the chief oxygen-carrying protein of the red blood cells,

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* Application density is discharge rate divided by the coverage area, which is 150 sq ft for these tests.

**K factor, a number to indicate the sprinkler discharge capacity, is defined as the discharge rate, W, divided by the square root of the discharge pressure, Δp, i.e., $K = W\ (gpm)/[\Delta p\ (psig)]^{0.5}$

TABLE I

SPRINKLER DISCHARGE VARIABLES

Sprinkler Discharge Pressure Δp (psig)		Sprinkler Orifice Diamater, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	Water Discharge Rate W (gpm)	15.0	8.8	6.0				
	Application Density (gpm/ft^2)	0.100	0.059	0.040				
	Local Application Density on Couch (gpm/ft^2)	0.081	0.044	0.036				
	K Factor	5.30	3.11	2.12				
	Relative Drop Size, d	1	0.826	0.731				
28.5	Water Discharge Rate W (gpm)			11.5	7.0	3.9		
	Application Density (gpm/ft^2)			0.077	0.047	0.026		
	Local Application Density on Couch (gpm/ft^2)			0.051	0.033	0.015		
	K Factor			2.15	1.31	0.731		
	Relative Drop Size, d			0.479	0.412	0.340		
88.5	Water Discharge Rate W (gpm)					6.8	4.7	3.4
	Application Density (gpm/ft^2)					0.045	0.031	0.023
	Local Application Density on Couch (gpm/ft^2)					0.037	0.028	0.007
	K Factor					0.723	0.500	0.361
	Relative Drop Size, d					0.233	0.207	0.179

Note: Relative Drop Size, $d = (\Delta p/\Delta p_o)^{-1/3} (D/D_o)^{2/3}$

$\Delta p_o = 9.5$ psig

$D_o = 0.438$ in.

K Factor $= W/\sqrt{\Delta p}$

hemoglobin. This complex of CO and hemoglobin is termed "carboxyhemoglobin" (CO Hb); a 16-20 percent CO Hb saturation in venous blood will cause headache and an "abnormal visual evoked response".[6] The amount of CO Hb formation depends on concentration and exposure duration. It is estimated[6] that a 43-min exposure at 1000 ppm, 100 min exposure at 500 ppm or a 400-min exposure at 200 ppm will result in a 20 percent CO Hb saturation in blood. The integrated values of CO concentration over the corresponding exposure period for each of these conditions is at least 43,000 ppm-min. This integrated value, 43,000 ppm-min, has been used as the criterion for evaluating the CO hazard in this test program.

Table II presents the CO concentration at eye level near the center of the living-dining area. At the commencement of flaming, CO concentration was in the range of 300-360 ppm. For the three discharge conditions: 1) 0.438-in. sprinkler at 8 psig (15 gpm), 2) 0.329 in. sprinkler at 8 psig (8.8 gpm), and 3) 0.164 in. sprinkler at 88.5 psig (6.9 gpm), the CO concentrations were maintained below 450 ppm during the entire test period, as shown in Table II.

For the rest of the tests, CO concentration increased during sprinkler operation but at much smaller rates than those of typical room fires[7] without sprinkler protection. The maximum values of CO concentration range from 1630 to 2500 ppm. For two of the sprinkler-discharge conditions (0.164-in. sprinkler at 28.5 psig and 0.110 in. sprinkler at 28.5 psig), CO measurements were not performed correctly and have, therefore, not been reported.

The cumulative CO concentration (ppm-min) are shown in Table III, at 5, 10 and 20 min after sprinkler activation. For all the tests with

TABLE II

CO CONCENTRATION (ppm) AT EYE LEVEL

Sprinkler Discharge Pressure Δp(psig)		Sprinkler Orifice Diamater, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	CO at t_f	360	320	330				
	CO at t_s	320	240	250				
	CO at t_s + 5 min	230	320	570				
	CO at t_s + 10 min	150	250	1180				
	CO at t_s + 20 min	110	230	1440				
28.5	CO at t_f			340	310	-		
	CO at t_s			110	210	-		
	CO at t_s + 5 min			1400	750	-		
	CO at t_s + 10 min			2130	1650	-		
	CO at t_s + 20 min			2010	1850	-		
88.5	CO at t_f					330	300	-
	CO at t_s					280	280	-
	CO at t_s + 5 min					335	740	-
	CO at t_s + 10 min					420	1320	-
	CO at t_s + 20 min					370	1730	

Note: t_f - time of flaming from ignition

t_s - time of sprinkler activation from ignition

TABLE III

CUMULATIVE CO CONCENTRATION (ppm-min)

Sprinkler Discharge Pressure Δp (psig)		Sprinkler Orifice Diameter, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	CO to t_f	4,650	4,370	6,720				
	CO to t_s	5,050	4,680	7,030				
	CO to t_s + 5 min	6,420	6,200	8,830				
	CO to t_s + 10 min	7,430	7,570	13,780				
	CO to t_s + 20 min	8,980	9,870	27,Q80				
28.5	CO to t_f			4,120	4,830	—		
	CO to t_s			4,520	5,270	—		
	CO to t_s + 5 min			7,550	6,480	—		
	CO to t_s + 10 min			17,030	11,470	—		
	CO to t_s + 20 min			39,780	28,920	—		
88.5	CO to t_f					4,780	5,820	—
	CO to t_s					5,100	6,080	—
	CO to t_s + 5 min					6,505	8,030	—
	CO to t_s + 10 min					8,080	13,720	—
	CO to t_s + 20 min					11,700	29,650	—

Note: t_f - time of flaming

t_s - time of sprinkler activation

reliable measurements, the cumulative CO concentrations at the end of the test (20 min after sprinkler activation) were less than 40,000 ppm-min which is below the estimated critical integrated value (43,000 ppm-min). For the lowest water discharge pressure (8 psig), the 0.274-in. sprinkler discharging 6 gpm kept the cumulative CO concentration below 28,000 ppm-min until the end of the test, 33 percent below the estimated critical value.

The gas temperature at eye level at the time of sprinkler activation and 1 min after sprinkler activation is listed in Table IV. This temperature was measured at 54 in. from the floor, 36 in. from the east and the north walls, approximately 2.5 ft from the flame axis. At the time of sprinkler activation, its value was in the range of 131-159°F.

The gas temperature dropped sharply after sprinkler operation. At 1 min after sprinkler activation, the gas temperature at eye level was below 92°F for all the tests as shown in Table IV. The hazardous levels for heat exposure reported by Yuill[8] are 212°F for 1/2 hour, 150°F for 1-2 hours and 120°F for 8 hours. Therefore, for all the sprinkler conditions tested, the danger of overexposure to heat was very slight.

A residential sprinkler protection system is intended to maintain a survivable environment of the fire room for a limited period of time, sufficient for occupants to be rescued (or to escape). A period of 20 min, after sprinkler operation appears reasonable. Based on the consideration of life-safety protection, judged from the CO concentration and gas temperature measurements at eye level, the following two sprinkler discharge conditions have been selected as a basis for the design of low-cost systems: 0.274-in. sprinkler operating at 8 psig and 6 gpm, and 0.137-in. sprinkler operating at 88.5 psig and 4.7 gpm. These

TABLE IV

GAS TEMPERATURE AT EYE LEVEL (F°)

(4 ft. 6 in. from floor, 3 ft. from north wall)

Sprinkler Discharge Pressure Δp (psig)		Sprinkler Orifice Diamater, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	T_{ei}	70	75	84				
	T_e	150	144	147				
	T_e'	80	76	89				
28.5	T_{ei}			68	71	72		
	T_e			137	147	156		
	T_e'			81	85	85		
88.5	T_{ei}					74	76	79
	T_e					137	159	131
	T_e'					83	89	92

Note: T_{ei} - gas temperature at start of test

T_e - gas temperature at time of sprinkler activation

T_e' - gas temperature at 1 min after sprinkler activation

two discharge conditions require smaller water discharge rates than that required by NFPA 13-D standards, but still provide adequate life-safety protection in fires of the kind studied in this program.

Although the "smokiness" in the sense of visibility is not judged to be a critical factor in the survivability of a sprinkler fire, the optical density is still of considerable interest. Table V presents optical density at eye level. It is interesting to note that, for the 0.438-in. and 0.329-in. sprinklers at 8 psig, the optical densities eventually decreased after activation of the sprinkler.

5.2 PROPERTY PROTECTION

The ability of the sprinkler to provide property protection was evaluated by analyzing the ceiling temperature history over the source of the fire and the gas temperature behavior at several points near the ceiling in the fire room.

Table VI shows the ceiling temperature (thermocouple C1) at a point directly above the ignition point. Temperatures at the time of sprinkler activation (the maximum ceiling temperature during the test) and 1 min. after sprinkler activation are presented for all nine sprinkler conditions. As is shown, peak ceiling temperatures reach between 250 and 350°F. The ratio $(T_c - T_c')/(T_c - T_{ci})$ where T_c = ceiling temperature at sprinkler activation, T_c' = ceiling temperature at 1 min after sprinkler activation and T_{ci} = ceiling temperature at the start of the test, indicates the degree of cooling that is achieved in the 1 min after sprinker activation. For all nine cases, the ceiling temperature was reduced below 220°F after 1 min of sprinkler operation. Cellulosic and plastic materials usually start to pyrolyze vigorously around a temperature of 500°F[9]. Hence, the sprinkler protection was more than sufficient to prevent the fire spread to the building structure.

TABLE V

OPTICAL DENSITY AT EYE LEVEL (ft^{-1})

Sprinkler Discharge Pressure Δp(psig)		Sprinkler Orifice Diameter D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	OD at t_f	0.44	0.27	0.30				
	OD at t_s	0.43	0.25	0.27				
	OD at t_s + 5 min	0.54	0.57	0.59				
	OD at t_s + 10 min	0.41	0.48	-				
	OD at t_s + 20 min	0.26	0.35	-				
28.5	OD at t_f			0.32	0.27	0.20		
	OD at t_s			0.23	0.27	0.16		
	OD at t_s + 5 min			0.61	0.94	0.45		
	OD at t_s + 10 min			0.60	0.54	0.75		
	OD at t_s + 20 min			0.45	0.60	0.62		
88.5	OD at t_f					0.44	0.20	0.07
	OD at t_s					0.35	0.16	0.10
	OD at t_s + 5 min					0.50	0.63	0.29
	OD at t_s + 10 min					0.53	0.44	0.37
	OD at t_s + 20 min					0.58	0.51	0.74

Note:

t_f - time of flaming

t_s - time of sprinkler activation

TABLE VI

CEILING TEMPERATURE DIRECTLY ABOVE THE IGNITION POINT (°F)

Sprinkler Discharge Pressure Δp(psig)		Sprinkler Orifice Diameter, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	T_c	283	333	306				
	T_c'	173	203	219				
	T_{ci}	70	72	84				
	$(T_c - T_c')/(T_c - T_{ci})$	0.52	0.50	0.39				
28.5	T_c			264	276	311		
	T_c'			172	224	216		
	T_{ci}			70	70	72		
	$(T_c - T_c')/(T_c - T_{ci})$			0.47	0.25	0.40		
88.5	T_c					265	337	262
	T_c'					186	208	209
	T_{ci}					77	79	84
	$(T_c - T_c')/(T_c - T_{ci})$					0.42	0.50	0.30

Note: T_{ci} - Ceiling temperature at start of test

T_c - Ceiling temperature at time of sprinkler activation

T_c' - Ceiling temperature at 1 min after sprinkler activation

VI CONCLUSIONS

Sprinklers have been shown capable of providing life-safety and property protection in a common fire scenario leading to fire deaths in the home. Furthermore, water discharge rates considerably below those provided by NFPA 13-D have been shown to be adequate.

The fire scenario simulated in the experimental program was a cigarette dropped into the crevice of a couch in the living room, with subsequent initiation of smoldering and eventual transition to flaming. Typically, transition to flaming occurred after a smoldering interval of 60 min. Generation of smoke and CO became vigorous only in the final 15 min before flaming; however, CO concentrations before flaming never exceeded 360 ppm at eye level. Up to flaming, the environment was deemed survivable.

A total of nine combinations of sprinkler size and water discharge were investigated. Survivability was judged from CO concentrations and temperatures measured at eye level in the living room for a time period extending to 20 min past sprinkler activation. Structural (property) protection was judged from gas temperatures under the ceiling[10] and surface temperatures in the ceiling. All test combinations of sprinkler size and water pressure provided more than adequate structural protection. Some test combinations also provided adequate life-safety protection on the basis of the adopted survival criteria.

The water density distribution of a sprinkler has been identified as an important factor in controlling the generation rate of CO.[10]

One low-pressure and one high-pressure combination were selected for future consideration in low-cost systems, both providing conservatively adequate life-safety and property protection in the test fires:

a 0.274-in. sprinkler at 8 psig (6 gpm) and a 0.137-in. sprinkler at 88.5 psig (4.7 gpm). The former discharges water at a rate which is 40 percent of the NFPA 13-D standard.

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8. Yuill, C.H., "Physiological Effects of Products of Combustion," ASSE Journal, February 1974, pp 36-42

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That concludes my presentation.

MR. KUCHNICKI: Dick Kuchnicki, National Association of Home Builders. Would you have a smoke detector in that test room?

DR. KUNG: Yes, we had smoke detectors in part of the test. This was outside the scope of the program. The photoelectric detector was activated approximately between 10 and 20 minutes after ignition.

MR. KUCHNICKI: It seems to me, then, that if the detector went off so much sooner than the sprinkler, what purpose does the sprinkler serve. Are't we trying to get the people out of the burning building? The smoke detector serves its purpose. Then if we only had a sprinkler in there, for instance, the smoke probably would have killed the occupants in that building.

DR. KUNG: As the data show, at the time of sprinkler activation, the environment was still survivable. It had only about 360 parts per million carbon monoxide. Also, we had some animals, rats, in the test and every single rat survived at the end of the test.

The point is, that for a small fire, at the time for sprinkler activation, the environment is not as bad as you had thought.

MR. KUCHNICKI: It seems to me that we have a complicated situation. It was shown in a table earlier today where, if you had a smoke detector, you could decrease the life loss by so much, that if you had sprinklers you would decrease the life loss by so much. The table seems to be over

simplified. Here, you see, the detector goes off before the sprinkler. It seems to me that this factor has to be built into our studies also. It seems to me that there's an interrelationship there.

MR SHAW: Harry Shaw, a comment. There are several ways to reduce fire losses

We look at smoke detectors, and everybody says, "what are they doing?" We say, they are saving people because we have isolated instances where it happened. But, in fact, we don't know what smoke detectors are doing. What's more, we don't know what they will be doing in five years.

What we do know is that we have a problem that results in $4 billion worth of losses, 6,500 lives, and a couple of hundred thousand injuries annually. We want to use every conceivable weapon to help solve that problem.

Smoke detectors will play a role. Suppression systems play a role and may play a bigger role, depending on what we come up with. It's conceivable that with the right research and the right development we might be able to equip a room for $50, may $35. We may find it's cost-effective to use sprinklers.

We also have the remote alarm system. What we're doing is exploring all these possibilities.

MR. MADDEN: Bob Madden, Fire Equipment Manufacturers' Association. Was there fuel loading in the room other than what is shown on the couch itself? Was there any other fuel contribution, whether from the structure itself to the fire, or other pieces of furniture?

DR. KUNG: Yes, there was another piece of furniture, a room divider, which was about three feet from the couch. The fire never spread to it.

But in our current program, we have developed a standard fire test method which Ray Praetz will talk about. We will have curtains behind the couch, and also carpet underneath the couch to investigate the fire spread to the adjacent combustibles.

MR. MADDEN: Are you seeing a relationship, however, between your sprinkler density that performed in this particular test and the amount of fuel loading that you're putting in there, as we would relate it, say, to an industrial fire-loading situation?

DR. KUNG: In the residential fire, when the sprinkler was activated, the fire was much smaller than an industrial fire. So as long as we prevent fire spreading to the adjacent combustibles, it will be safe. And we use the fast response link. So when the fire -- when the sprinklers were activated, the fire was only 24 inches wide.

MR. CUSTER: Dick Custer, Center for Fire Research. I have two questions, one relating to your determination of the parts per million minutes of CO. Your point where you began the integration, it was sprinkler operation correct?

DR. KUNG: It was at the moment when we put that heating coil on the couch.

MR. CUSTER: All right. You integrated from the --

DR. KUNG: The very beginning.

MR. CUSTER: -- the very beginning. I guess that looks a little different from what Graham Clark has in the performance specifications. The specifications start at 20 minutes.

DR. KUNG: They're just the same.

MR. CUSTER: We'll get to that this afternoon. The other question concerns what I remember from looking at your report; there were ventilators exhausting the test area, and you had an outside supply of fresh air. Do you think this has any effect -- somewhere around three air changes an hour? Do you think this has any effect on the CO measurements?

DR. KUNG: Yes, I think it will have some effect, and the reason is, if we run a fire test with a similar couch, without any air conditioning, and we measure the same kind of CO concentration, like a 1000 parts per minute during the sprinkler operation, I figure the contribution from the air condition underneath the window, the air conditioning unit, would not change the results so drastically.

MR. CUSTER: You did not see any difference?

DR. KUNG: As far as the order of magnitude is concerned, they are the same. For tests without any air conditioning, the doors and windows were closed.

MR. CUSTER: But you still had the two exhaust fans operating?

DR. KUNG: They were closed in the new test.

MR. CUSTER: Those test results are not in the draft report?

DR. KUNG: Not in this report.

MR. DOSEDLO: Lee Dosedlo, Underwriters Laboratories. I noted in your work that about the only toxic gas or gas that was being monitored was carbon monoxide. Normally, when products are burned, the products of combustion, especially foam-stuffed furniture, produce many other toxic gases, such as cyanides and hydrocarbons, analines, and CO_2 and so forth. This work is supposed to be showing that you are maintaining a tenable environment. What about measurements of these other toxic gases?

Also, how do you relate the measurement of the CO content in the room versus CO content in a person's bloodstream? Because the intake of the CO_2 is a major factor, and that's affected by both the CO_2 and temperature. I was wondering what the relationship is.

DR. KUNG: The Fire Fatality Study conducted by APL shows that CO alone is the cause of death in 50% of the cases. A combination of CO and factors such as pre-existing heart disease, high levels of blood alcohol were blamed for the other 30% of the fatalities studied. Therefore, we chose CO concentration at eye level as a yardstick to evaluate survivability within the environment. In addition to CO measurement, we also monitored CO_2 and O_2 concentration at eye level continuously. The measured levels of CO_2 and O_2 deficiency were very low compared with the hazardous levels. However, the effect of a combination of several toxic gases on humans is still not well understood.

MR. PIETRZAK: Larry Pietrzak, Mission Research. The condition you tested, would you make some prejudgment as to whether the specific geometry of the ventilation and the fuel conditions were stressful or critical, that they in fact stressed the system that you investigated? Or would you

look at alternative configurations? In other words, can we be assured that these are conservative results from a wide range of conditions that exist in residential homes?

DR. KUNG: I think the configuration we chose is typical and it is a small residence. Since the residence is small, it presents a more severe test for maintaining a survivable environment.

MR. PIETRZAK: An environmental factor rather than a specific analytical assessment of the possibilities.

MR. O'NEILL: NATIONAL BUREAU OF STANDARDS, CENTER FOR FIRE RESEARCH: Have you included in your report the method that you used for 43,000 parts per million CO to equate that it is only 20% COHB?

DR. KUNG: Yes, it was explained that way in the report.

MR. O'NEILL: Second question. How did you vary the height of your gas analysis to ensure that the point of CO sampling was at the 5 ft. level inside the room in terms of people sitting in the room?

DR. KUNG: We would like to verify that, but we did not have the budget to allow us to make more measurements. However, the CO sampling location was almost in the center of the room and probably was representative.

MR. HAYES, NATIONAL BUREAU OF STANDARDS: Did you in fact measure the CO concentration after sprinkler operation?

DR. KUNG: Yes. We had the continuous CO measurement from ignition to 20 minutes after sprinkler operation.

MR. EARLY, MONSANTO: You mentioned two pressure levels in your system - 8 and 88.5.

DR. KUNG: Yes.

MR. EARLY: I wonder why the 88.5 when we have generally less than 88.5 lbs. in our homes.

DR. KUNG: Well, the investigation with 88.5 psig when an exploratory work for the self-contained system; we feel that the self-contained system would have high pressure. The 8 is for systems connected to the domestic water.

MR. BENJAMIN, NATIONAL BUREAU OF STANDARDS: I am a little bit confused about recommendations that the two levels of water that you have proposed are adequate to keep survivable environment in the room, particularly, since as far as I can see from your report, it was only for a particular type of material tested, and it seems to me you generalized an awful long way on one particular type of material.

DR. KUNG: All these data only pertain to that one type of material. Afterward, we have run tests with two different types of material. The recommended sprinkler conditions were used, and the sprinkler did provide adequate protection based on the adopted criteria.

EXPERIMENTAL INVESTIGATION OF LOW-COST SPRINKLER SYSTEM CONCEPTS

Norman C. Henderson
Battelle Columbus Laboratories

I'd like to personally welcome everybody to this conference. I am pretty confident that we're going to end up with at least the potential for some significant life-saving capability as a result of it. I feel like one of the sweathogs of Kotter's TV show, having written my crib notes on a sandwich and forgotten about it, and then eaten my sandwich. I was anticipating a much smaller and more informal group. I hope all of you can see my squiggles projected from the Vugraph on the wall.

The subject of my presentation is also low-cost sprinkler systems geared to the residential environment. It's a companion program to that which you just heard from Factory Mutual. A significant portion of our experimental work was devoted to the concept of water minimization, the premise being that with minimum water usage, one also has a high potential to design a miniaturized sprinker system, with correspondingly low installation and material costs. That is the premise for our work.

All of our major experiments were conducted in a relatively small room, 12 ft. x 12 ft. in area, and 8 ft. ceiling height. It

was especially constructed for this work: fire-resistive construction used throughout, mainly to keep the room from burning down in case things got out of control.

We had five distinct experimental phases. The first phase was a series of thermal mapping experiments, ending up in a rather large spectrum of thermal contour maps at various elevations in the room, describing what happens temperature-wise as a function of time.

The next major experimental phase involved water interactions, that is, water spray interactions, with a programmable propane fire burner which we designed for the program. This propane burner - the idea for it was again to save time and cleanup - enabled us to conduct a large number of fire tests at minimum cost.

The third phase of experimental fire work involved crib fire tests. Now we're progressing from a somewhat more realistic environment, that is, from an essentially non-extinguishable gas flame heat source to a not readily extinguishable, but an extinguishable fire source, namely, that of a wood crib. From the wood crib fires, we progress to furniture fires, again using water for our furniture interactions.

And our last series of tests was to document the water distribution patterns produced by the various spray heads and spray nozzles used in the program. I would just like to highlight some of our work.

Figure 1 a temperature-time curve for a commercially approved sprinkler. The data were obtained by a horizontal grid of therocouples. We used 9 x 9 thermocouples, obtaining a total of 81. The data were obtained every ten (10) seconds by averaging all 81 thermocouples to produce on point every 10 seconds. So every 10 seconds along that curve is the average of 81 thermocouple data points. The gridwork was positioned fairly close to the ceiling, about an inch down from the ceiling.

The temperatures you will see on the projected curves are representative of an average of the whole room ceiling area, and are not a maximum, as would occur directly over the fire.

The next curve, Figure 2, shows the time-temperature plot for one of our experimental nozzles. It's a commercially available unit. We labeled it a Fogjet. It was obtained from Spraying Systems, Inc., in Cleveland. This particular nozzle's curve was based on a flow of one gallon a minute. The fire source used was that of propane.

You can compare the curve in Figure 1 with the curve in Figure 2.

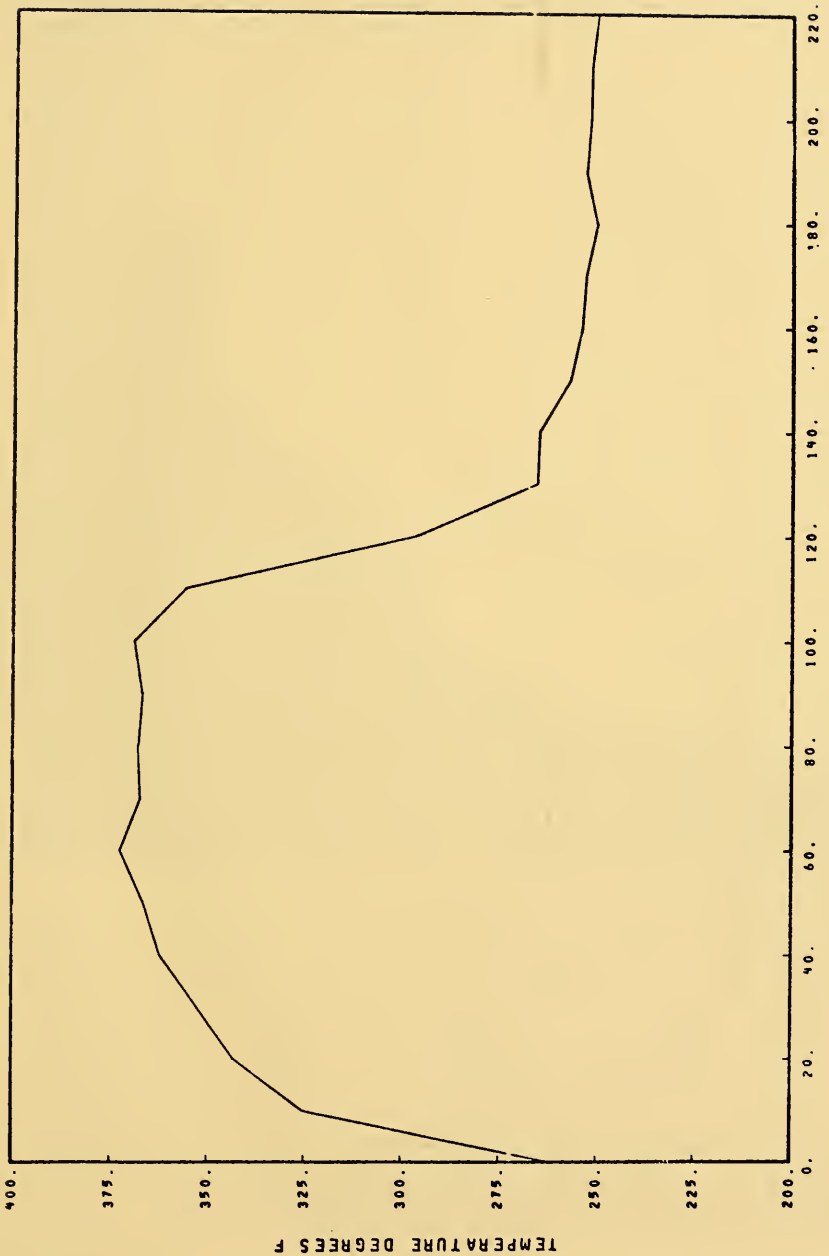


FIGURE 1 . TIME TEMPERATURE CURVES FOR NOZZLE STAR, RUNS 151, 152

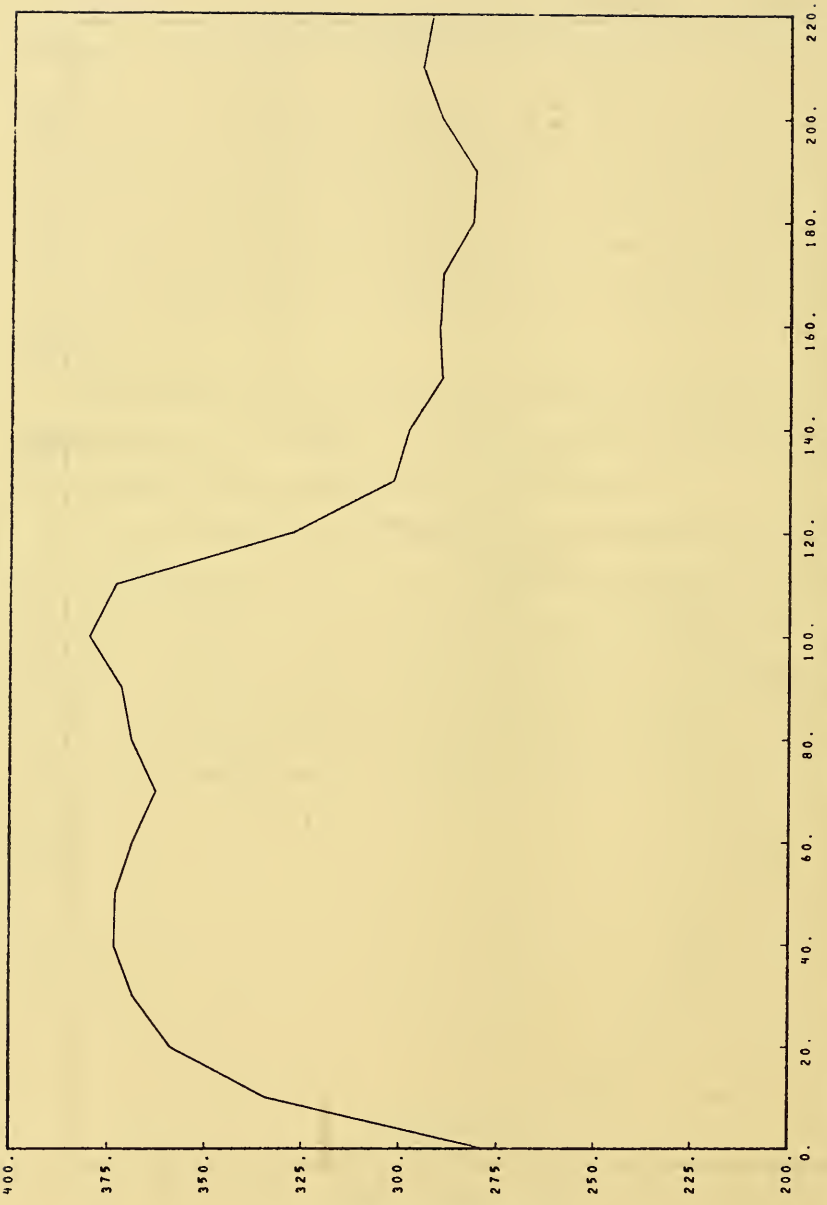


FIGURE 2. TIME TEMPERATURE CURVES FOR NOZZLE SS FOGJET 10, RUNS 155, 156

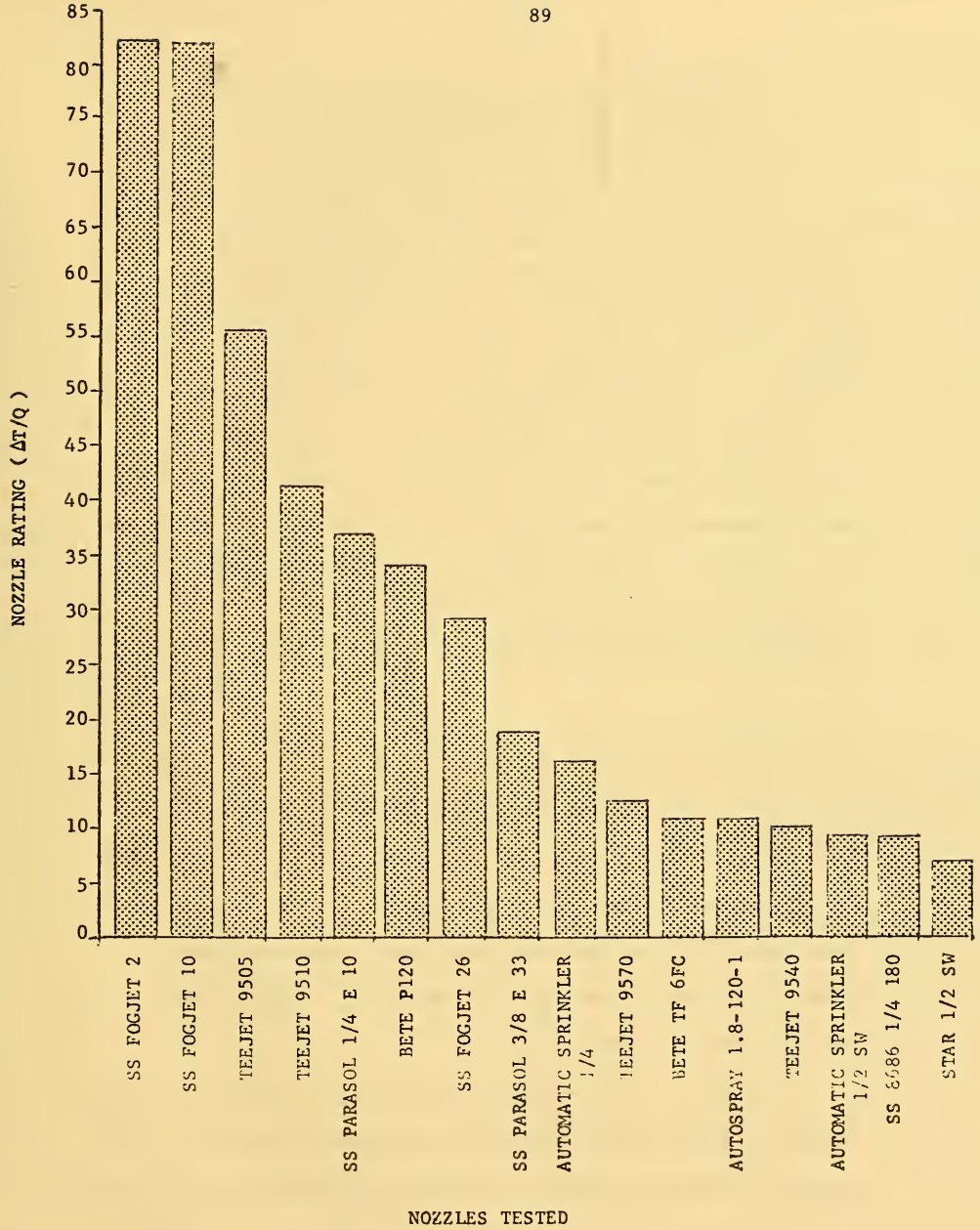


FIGURE 3 CALCULATED NOZZLE RATING BASED ON EXPERIMENTALLY RECORDED DATA FOR NOZZLES TESTED USING PROPANE FUELED STANDARD FIRE

As you can see, the two curves represent in the first case the water flow of 15 gallons per minute, and in the second case, a water flow of 1 gallon a minute. Obviously, we have a little more significant effect with 15 per minute. But you can still see, even though there is a difference of 15 gallons per minute, that the results are significant in both cases, from the viewpoint of lowering ceiling temperature after water application.

What we did in this diagram. Figure 3, is plot what we call nozzle ratings. These ratings were obtained by dividing the net temperature drop after water spray activation, comparing that temperature with that which occurred before, the maximum termperature achieved before the water was turned on, and dividing that by the water flow. We synthesized a term called nozzle rating.

Figure 3 represents, on the lower portion of the graph, a list of all the nozzles that were used in the propane fire experiments. We ordered them in decreasing order of nozzle rating. You can see toward the left of the curve - this happens to be this Fogjet 10 - the spraying system nozzle mentioned before. Toward the right are some of the commercially available nozzles. In between, there's a mix.

Not only is the so-called nozzle rating, a term we invented, important, but actually, the ceiling temperature control is also important. In other words, you can have a hypodermic needle injecting

water into the room, and you'll have a tremendously high nozzle rating, if you will, but it will do nothing to the fire.

So from the other viewpoint is temperature control. In Figure 4 we retained the same order of decreasing nozzle rating, combined with the net temperature drops achieved with each of the nozzles. You can see the second nozzle from the left, that bar is fairly high, and not too far out of line with those achieved by some of the other nozzles tested to the right, even though the water flows were fairly normal.

Figure 5 demonstrates water flow as measured for the nozzles tested. In general, you can see that lesser water flow can be roughly correlated with increased nozzle efficiency. As I said before, I've got to warn you that that's not the whole picture. You've got to look at the fire control capability, the temperature drops, and so forth.

Figure 6 is an example of the temperature-time plot of the crib fires conducted. The nozzle used was operating at minimum 13-D standards, that is, a density of approximately .104 was the actual theoretical density used.

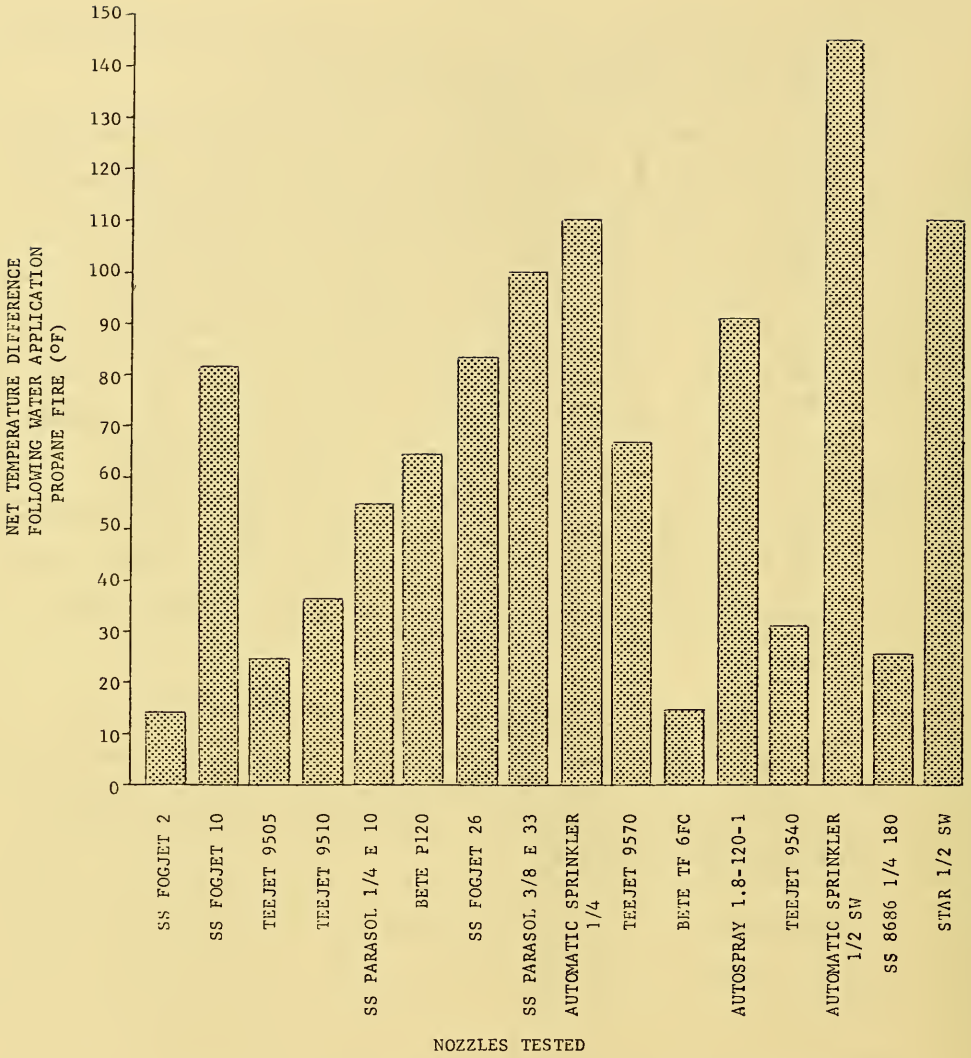


FIGURE 4. NET TEMPERATURE DIFFERENCE EXPERIMENTALLY RECORDED FOR NOZZLES TESTED USING PROPANE FUELED STANDARD FIRE

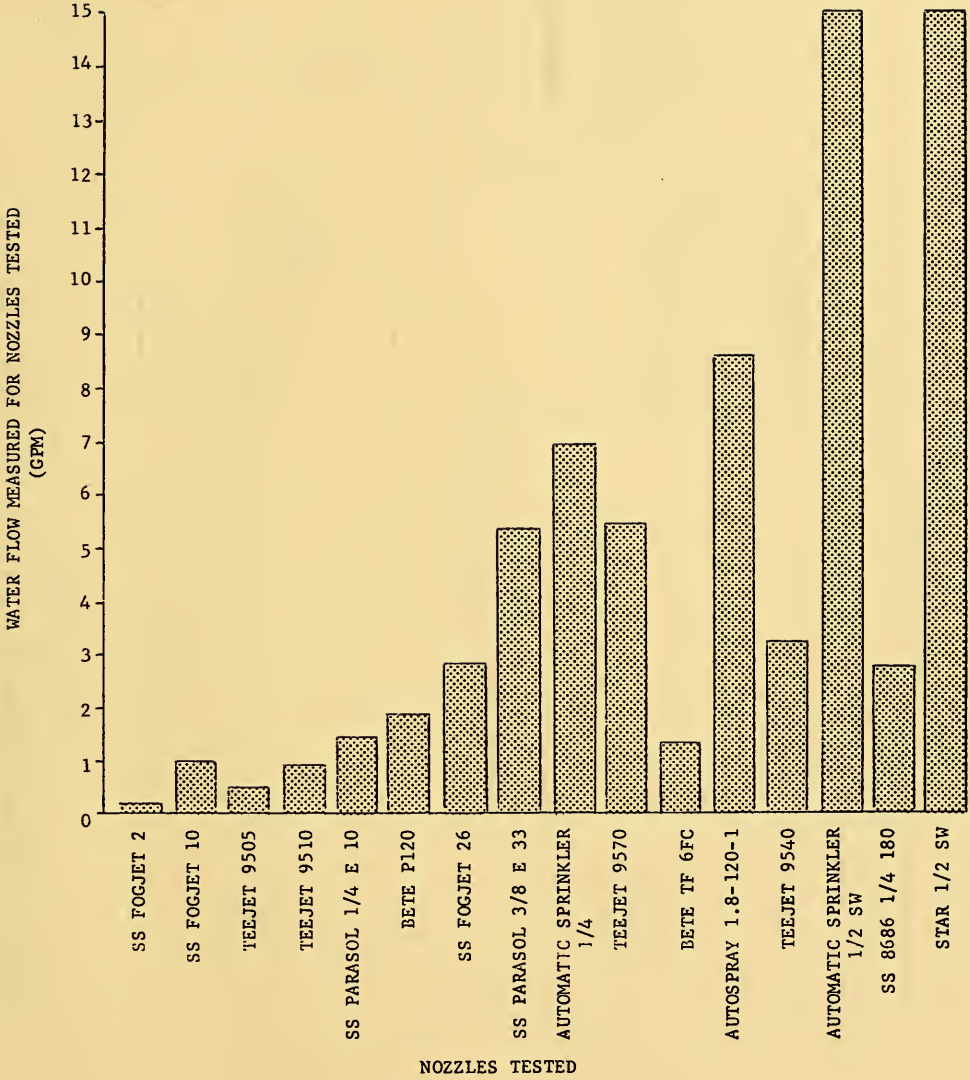


FIGURE 5 . WATER FLOW EXPERIMENTALLY RECORDED FOR NOZZLES TESTED

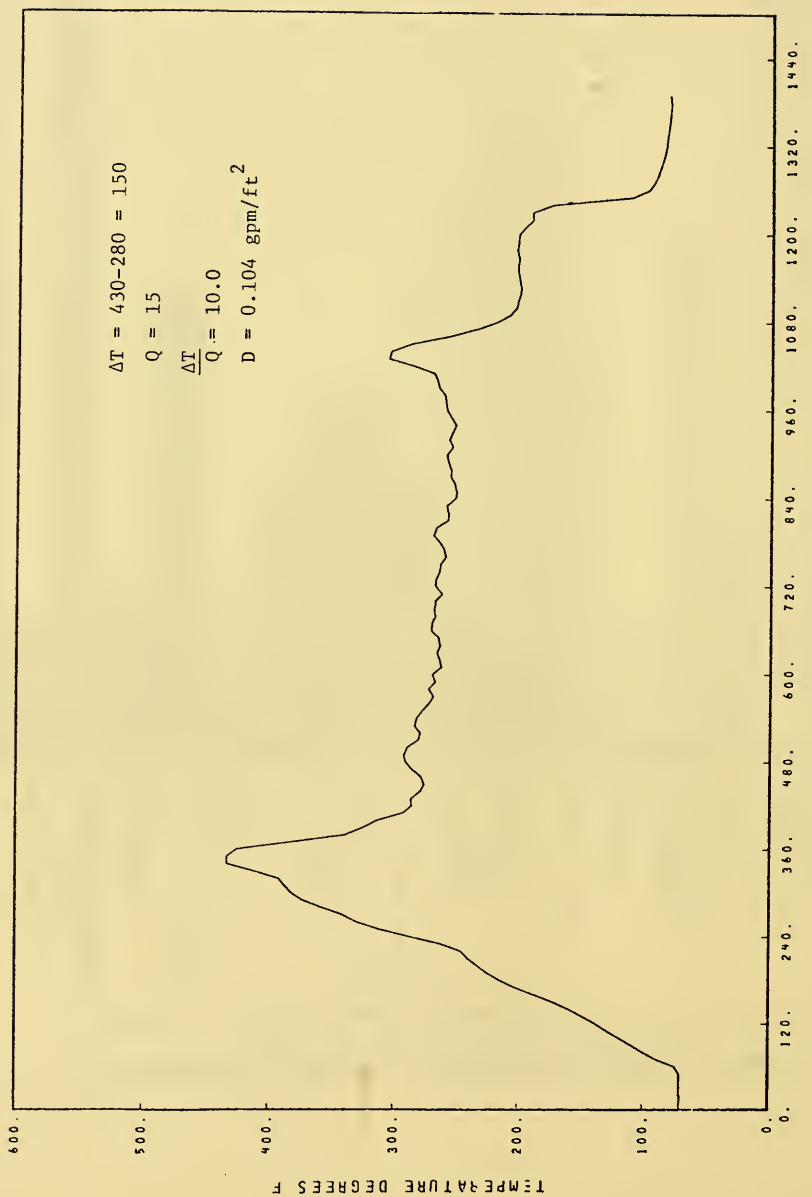


FIGURE 6. TEMPERATURE-TIME CURVE FOR STAR 1/2-IN PENDENT, RUN 210

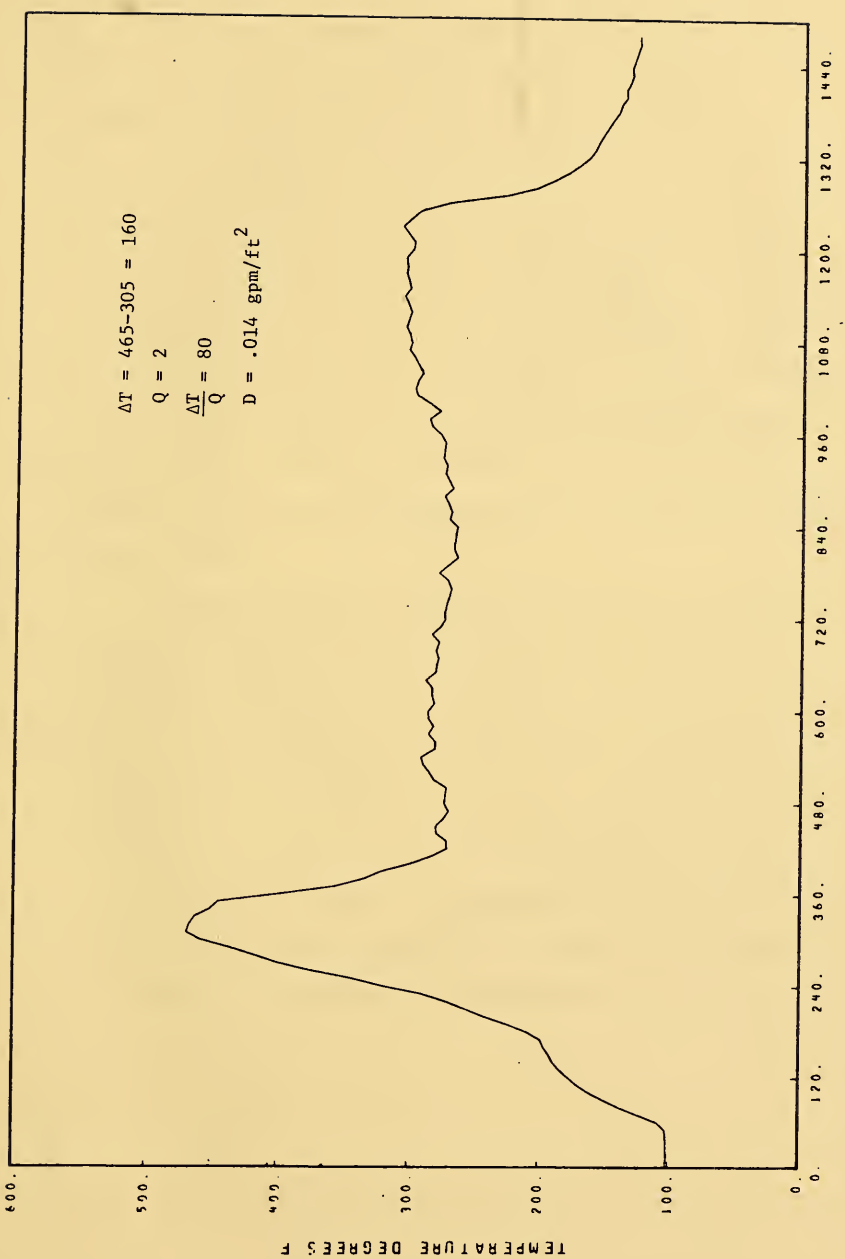


FIGURE 7. TEMPERATURE-TIME CURVE FOR 2 FOGJET NO. 10, RUN 215

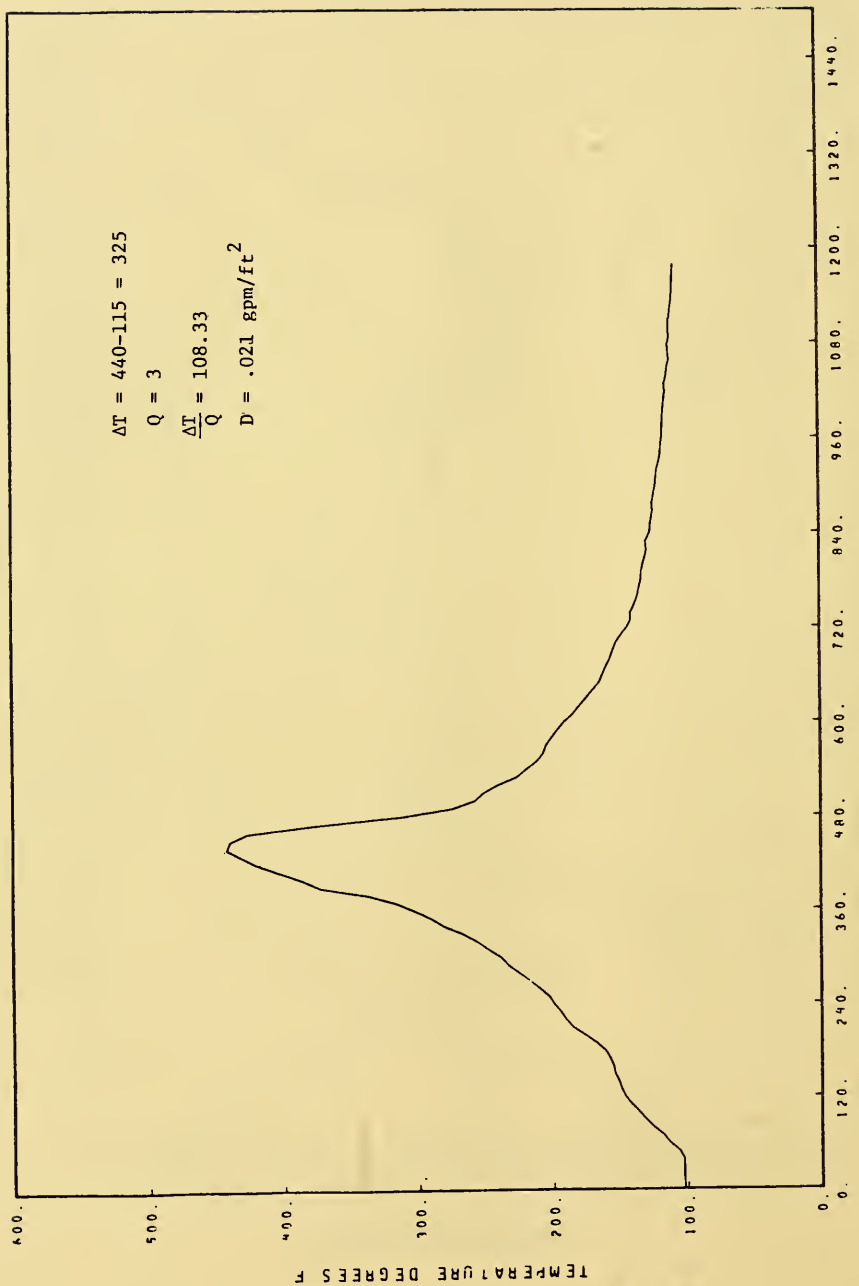


FIGURE 8 - TEMPERATURE-TIME CURVE FOR 3 FOGJET NO. 10. RUN 216

I'd like to compare the previous curve, Figure 6, with this one, Figure 7, which is for two Fogjet 10 nozzles, flowing in this particular case at two gallons per minute. One can't overlap the curves in this case because, unfortunately, the scales are different. But you can see that the ceiling temperatures, although not quite as good as that achieved for the .1 density, is at least similar. The average ceiling temperature is hovering around 300 degrees Farhrenheit. In this particular case, it's also evident that the crib fire, being potentially extinguishable, was not extinguished. In other words, the ceiling temperature was maintained at about 300 degrees Fahrenheit on the average.

Figure 8 shows what happened to the crib by increasing these Fogjet nozzles from two to three; in other words, from two gallons a minute flow to three gallons a minute flow. In this particular case, this is what the curves look like when entinguishment was achieved. It reached a peak, and proceeded to decrease until it cooled down, until the fire went out.

Figure 9 shows plots of the nozzle ratings for crib fires. We believe that the nozzle rating is a fairly valid concept, particularly for the propane fire experiments that we conducted.

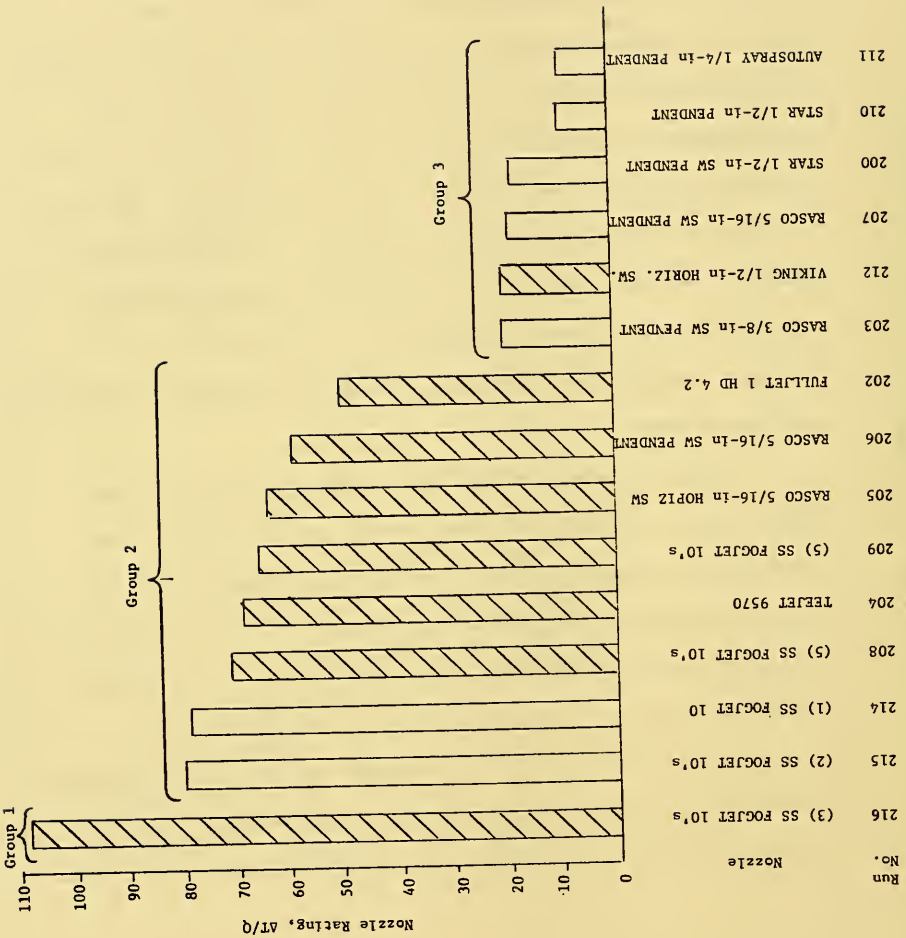


FIGURE 9. NOZZLE RATINGS CALCULATED FOR NOZZLES USED IN CRIB FIRE EXPERIMENTS

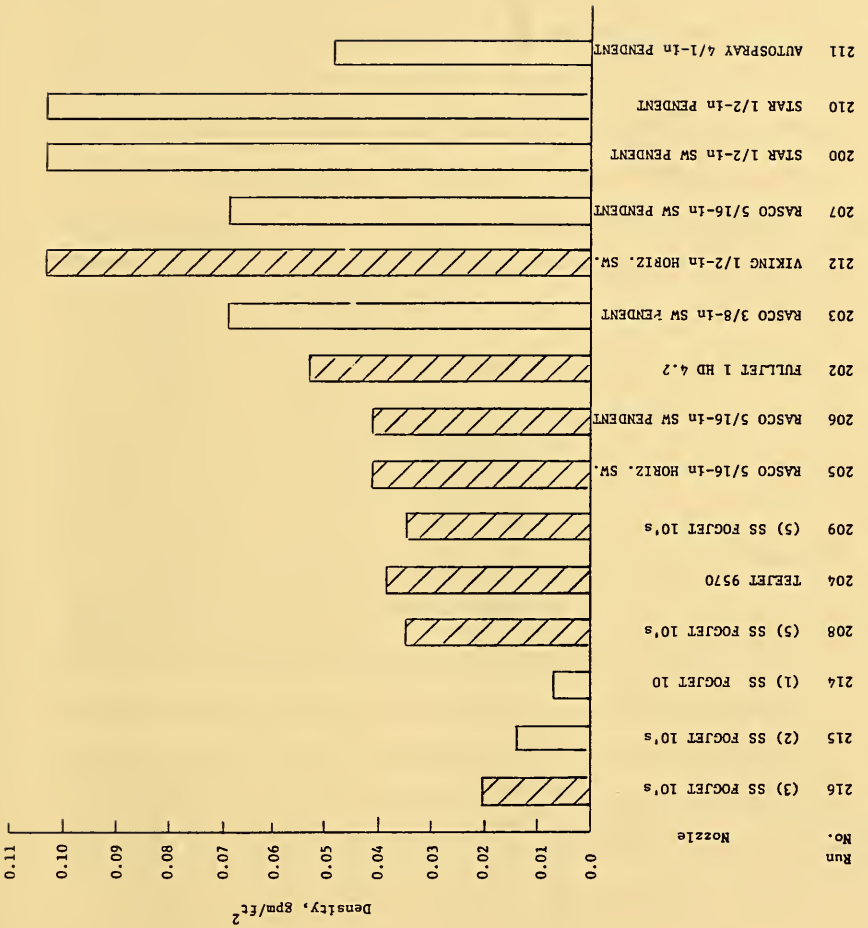


FIGURE 10. THEORETICAL WATER DENSITIES PRODUCED BY THE NOZZLES USED IN THE CRIB FIRE EXPERIMENTS

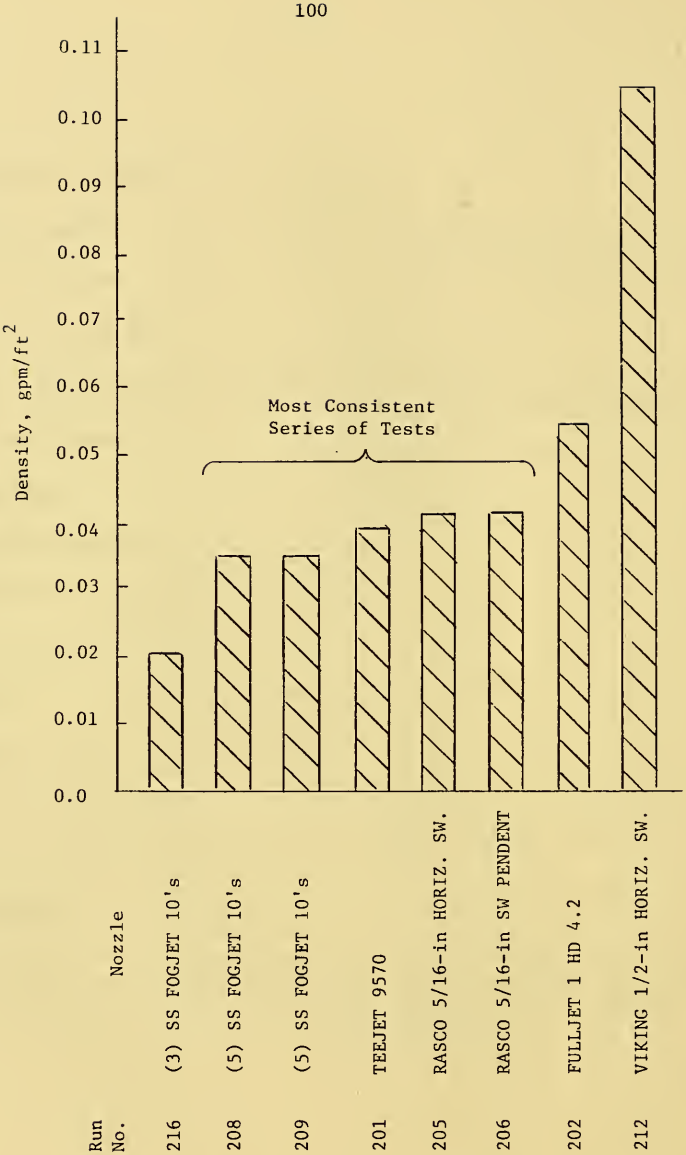


FIGURE 11. THEORETICAL WATER DENSITIES PRODUCED BY NOZZLES ACHIEVING EXTINGUISHMENT DURING CRIB FIRE EXPERIMENTS

If you think about this series of plots, especially when you have the added complication of extinguishment, it might appear that the nozzle rating concept, that is, the ability to control ceiling temperature, is not quite as valid. Nevertheless, you can see some trends show up. To the lift, on the nozzle listing column, Fogjet 10 shows a fairly high nozzle rating for some of the nozzles which use predominantly large water flows with lower nozzle ratings. Also in this chart, we have crosshatched some of the bars to indicate that extinguishment did occur.

Again, retaining that same order, Figure 10 plots the density produced by the various nozzles, and the same order of nozzle ratings shown before; again, crosshatching indicates where extinguishment occurred.

Figure 11 concerns the cases where extinguishment occurred; you can see that from a density viewpoint, we have a fairly consistent series. Coincidentally, you can see that the density of that most consistent series correspond very nicely with that work done by Factory Mutual. It is also significant to note that in the consistent series, the nozzles tested involved both commercially available sprinkler head nozzles, as well as just spray head nozzles.

Note Figure 12. Factory Mutual, in performing a very detailed analysis of quite realistic apartment fire conditions, used a technique which I think was excellent - that of integrating the CO levels over the time range of the experiment

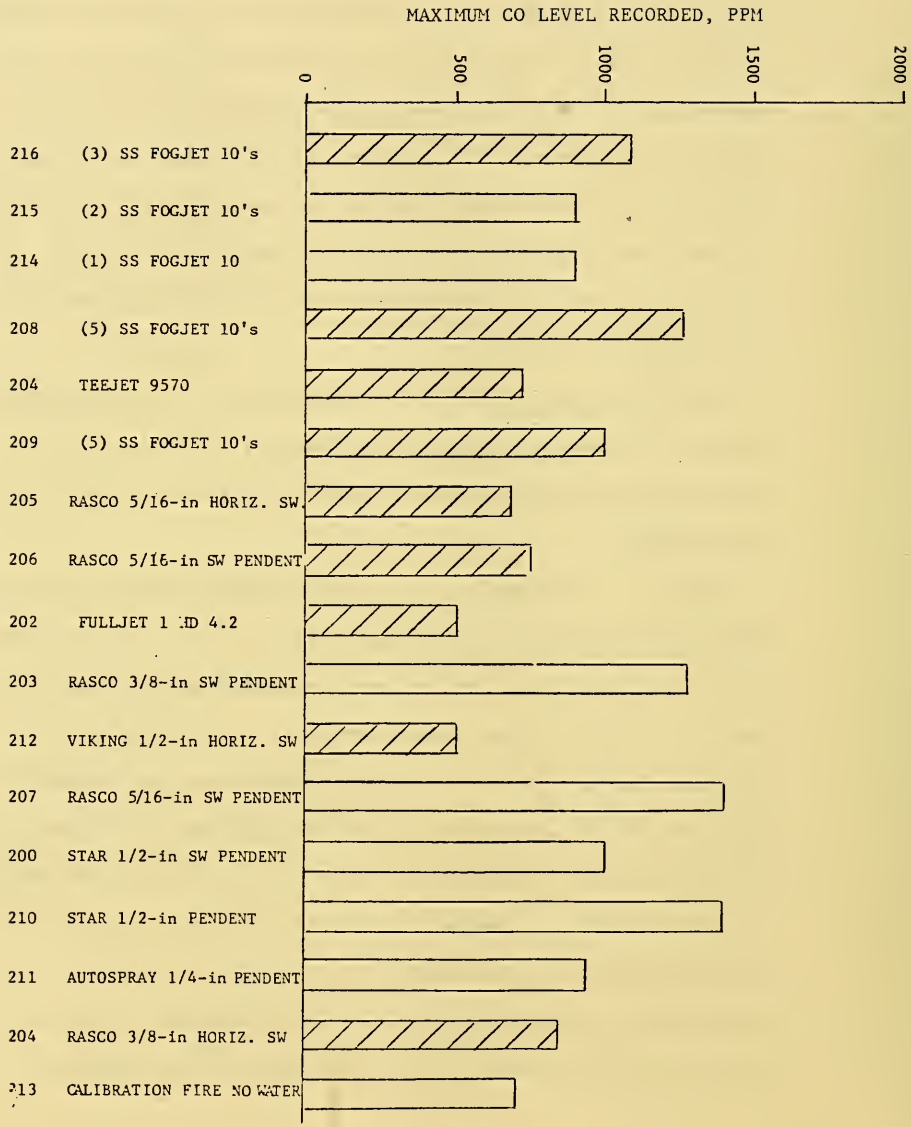

MAXIMUM CO LEVEL RECORDED, PPM
0
500
1000
1500
2000
216 (3) SS FOGJET 10's
215 (2) SS FOGJET 10's
214 (1) SS FOGJET 10
208 (5) SS FOGJET 10's
204 TEEJET 9570
209 (5) SS FOGJET 10's
205 RASCO 5/16-in HORIZ. SW
206 RASCO 5/16-in SW PENDENT
202 FULLJET 1 HD 4.2
203 RASCO 3/8-in SW PENDENT
212 VIKING 1/2-in HORIZ. SW
207 RASCO 5/16-in SW PENDENT
200 STAR 1/2-in SW PENDENT
210 STAR 1/2-in PENDENT
211 AUTOSPRAY 1/4-in PENDENT
204 RASCO 3/8-in HORIZ. SW
213 CALIBRATION FIRE NO WATER

FIGURE 12. MAXIMUM CO LEVELS PRODUCED FOR EACH OF THE NOZZLES TESTED DURING THE CRIB FIRE EXPERIMENTS

to deduce what the possible physiological effects might likely occur.

Our tests were initiated not in the smoldering stage at all, but were initiated at a fairly high, flaming stage of development. We did, however, monitor what the maximum CO levels reached in our experiments were.

We concede that in all cases they were below 1500 parts per million, and in only one case did we exceed 3000 parts per million; that was an experiment in which we were applying water at the code-approved density of .1. We shut the sprinkler off. The fire had not extinguished itself. The fire then continued to burn, at that point in time, that went into the crib - it was a crib fire - with the crib being wetted. The CO level went far above that obtained when either the water was turned on to the flaming crib, or what the flaming crib achieved on its own. In other words, it made things much, much worse from a CO concentration viewpoint.

The only reason I mention this is that for systems where we might have a limited store supply of 5, 10, 20 minutes, it may be conceivable that if we exceed that, we could run into CO concentration problems.

These charts have presented a highlight overview of the work we were doing. In summarizing some of the significant results that we had, I will say our experiments show that the potential exists to

potential exists to achieve fire control capabilities equal with that of a .1 density system, with water potentially as low as 1/15 that normally now required.

Some of our curves indicate that the potential exists that we can prevent flashover from occurring with water maybe as low as 1/15 of that now required; in other words, throwing one gallon a minute into the room versus 15 per minute.

With those comments, I'd like to open the floor.

MR. PIETRZAK: Larry Pietrzak from Mission Research. Did you make any attempt to understand why you were getting variations in all the various types of nozzles that you tested; why one was better than the other?

MR. HENDERSON: We made attempts to understand, but they were by no means conclusive. There were combinations of droplet size, water distribution, location of spray head relative to the fire. You can also add to it the specifics of our room tests. Ours is a fairly small room, a very specific case. All these combined for the effects noted. What we did think was significant was that we noticed the high potentials for success for various types of systems. But we can't prove many of the things that you want to know.

DR. BERL: Walter Berl, APL. When you used fog nozzles, did any water get down to your material burning, or was it mainly cooling hot gases?

MR. HENDERSON: It depended on the quantity that we actually used. The fog nozzles - what we did was run the fog nozzles at one gallon a minute, then we put two heads in to let two gallons a minute at the same spray pattern. Then three heads, and so forth; just a multiplicity of heads. In the case of entinguishment, we did do that. There was enough water in the room. And, finally, when the temperatures did get low enough, water did penetrate - did get down. It was difficult to observe anything in the fog. The environment optically looked much worse than it really was, from say a carbon monoxide or smoke density standpoint because of the steam generated. We thought, in many cases, the room looks terrible compared to other times. It was actually clean, carbon monoxide-wise. But it was very hard to view anything. All we could do was observe effects. After we were done, and the fire went out, things were wet. So obviously, at one point in time, it did get down and penetrate, when it didn't get out. The crib wasn't wet at all, or minimal wetting from the fog nozzles.

The Plan to Modify Sprinkler Standard NFPA 13-D

by

Chester Schirmer
President
Schirmer Engineering Corporation

Chairman, NFPA 13 Committee

My assignment is to discuss the plan to modify 13-D. First, I think maybe we should look at the history of 13-D. There was a recognition about four or five years ago of the residential fire problem within the NFPA and within the Sprinkler Committee. As a result, the Sprinkler Committee took on the task of preparing a separate standard to deal with one- and two-family dwellings and mobile homes. This assignment is actually part of the work of a subcommittee dealing with light hazard occupancies, particularly of a residential nature. We realized at that time that no one was going to install a typical full NFPA 13 system in a dwelling; we were aware that very few people were going to install such a system in anything other than commercial or industrial buildings where required by code or insurance requirements. As a result, the subcommittee moved to determine how to make a suppression system practical in one- and two-family dwellings. The group that worked on this had many meetings. One of the things that we encountered time and time and time again, regardless of all of the background and expertise of all of the people involved on that subcommittee, was the lack of data, a lack of test data, and a resultant lack of knowledge. There was no place to obtain any funding for testing.

During the course of those discussions there was quite a concern with the design density. We ultimately ended up with a 0.1 density and a ten-minute water supply. On a somewhat "scientific" basis we figured a 250 square feet operating area and a ten-minute water supply -- that's 250 gallons which happens to fit into a 275-gallon oil tank. Such a tank would be a suitable water storage facility common to dwellings. We also felt that one should be able to evacuate a dwelling in ten minutes. The subcommittee considered quite seriously trying to go to the lesser densities that are in the British standards and the Australian standards. That would have reduced densities down to the neighborhood of 0.06, 0.65 from the 0.1 specified in 13-D. But when you do not have data, when you do not have the facts and you write a standard, you must go in the conservative direction, particularly when you're moving in the direction we were moving in with very limited water supplies and with partial protection.

That's probably one of the main reasons that I am personally excited about what's going on in this conference. We're looking forward to making use of the contractors' work represented here. We now have data that were missing in our earlier considerations: The Jensen-Schirmer Report is available for 13-D. Byron Halpin's work will be available to us, and will be extremely valuable to put together in the fire scenario and the suppression system the factors which should interact with each other. Certainly all of the FM test work will be valuable to the subcommittee, as well as all of the test work that's been done at Battelle. The latter two will be melded together to develop some actual performance criteria as to what we expect the system to accomplish.

The "performance standard" which has been developed by FM will serve as somewhat of a guideline as work proceeds in revising 13-D.

I am hoping that with all of these reports and with this suggested performance standard, we will also have all the feed-in comments that have come to you, Harry, to expand on what is really in all of these documents and what the thinking is of the overall field that has been exposed to this material.

We are also looking forward to having the Proceedings of this conference available. The Proceedings are going to be extremely important, particularly in looking at the questions and answers that come out of this meeting.

The 13-D Subcommittee will start to deliberate in January of this year at a meeting in Washington. The revised standard will have to go from the 13-D Subcommittee into the full 13 Committee, and then, in the normal fashion, will come out in the NFPA Technical Committee Reports for public comment. These are available to anyone anywhere for comment. I would encourage everybody here to look at the revised standard very carefully when it is published in the TCR and I encourage your comments and input to the committee. If you have ideas from what you hear today, or you have ideas from what you don't hear today, drop a line to Rolf Jensen, chairman of the subcommittee, or to me and let us get it into the overall revision process. I anticipate also that the 13-D Subcommittee will have available to it additional test data. There are some tests that are still necessary. The residential system is going to have to be tested to failure. It is necessary and important to find out where it fails.

The system must also be tested on a two-sprinkler operation rather than a single sprinkler operation with the ignition directly under the sprinkler that operates. The point of ignition must be tested under the couch, as well as on top of the couch and the ignition source and couch should also be tested midway between the two sprinklers geographically laterally remote from the line between them. Some of these variables we may intuitively think we have the answers to today, but in the actual standards-making process, we're going to need as many verified answers as we can possibly get. I'm assuming, Harry, that with the cooperation from this group, it will be available to us.

Now there are some other related NFPA activities that we should be thinking about and be aware of. The Household Fire Warning Systems Standard was referred to by Byron. The input of Byron's report, the input as to what's going on in the residential suppression area, and the input from the ARRAS project -- Automatic Residential Remote Alarm System -- should be fed to the appropriate NFPA technical committees.

There's one other committee in NFPA that has been relatively inactive recently, and that's the Dwelling Fire Protection and Prevention Committee. I'm going to take it upon myself to try and get that committee a little more active because, ultimately, it should also be involved in the overall residential fire problem.

There have been some questions asked today about what is the effect of suppression plus detection. I know that many of the papers that we read and the performance standards we talk about all allude to detection in the areas that are not sprinklered.

We have to get this matter sorted out and have it put together in an overall package. This Friday the long-range plan of NFPA, which includes an objective or series of objectives related to the residential fire problem, will be approved by the NFPA Board. The goals included in this plan are totally compatible with, and fit in with, the objectives of the National Fire Prevention and Control Administration. These support each other beautifully.

What results, gentlemen, is exciting and good: Here is a super example of government working in cooperation with the private sector, each doing the thing that it can do best, but not encroaching on each other's "turf", if you will, but coming up with an an answer that is totally in the public good.

We all recognize that the residential fire problem is the biggest problem we have as far as fire in this country is concerned. I think that everybody in this room can be proud of being a part of trying to solve it.

One thing that I hope that we will all do, particularly as we move into the NFPA standards-making situation, is maintain this objective in our mind and not get hung up with a lot of little picky details along the way. We must stay with the objective. I think if we stay with the objective and work with the material that we have available, we'll be able to solve the residential fire problem.

If there are any questions, I'll be glad to try to field them.

MR. BOWMAN: Mike Bowman, Forest Service. We are quite concerned with the rural fire problem in our sector and quite interested in this system. We've monitored it over the last year or so. We feel an urgency in getting this prototype into the field for testing or implementation in the rural area.

Two questions. Number one, do you feel we're premature at this point in time in pushing ahead on a prototype for rural structures, summer homes, residences, whatever? And number two, is there anything that you know of on the market today or planned over the next year, a package that we could implement?

MR. SCHIRMER: I would say yes, you would be a little premature. I mentioned possible additional tests that I believe are necessary to develop a degree of confidence in the system.

You're going to have to look at your objective for rural dwellings. If your objective is the life safety of its occupants only, you're in one area. But if your objective is the protection of the property, you're going to be in an entirely different area, because the response time from a fire department is obviously going to be quite different than what we might contemplate in a 13-D system or in a performance standard system. We're not necessarily going to get total extinguishment with one of these if we run out of water. That just means if you've got the adjacent area wet down, it might take a little longer to burn it down if nobody comes along to help. So you've got to look at what your

objective is. Is it strictly life safety or is it property protection? If you're working in property protection, you're going to have to look at more complete coverage. You're going to have to look at possibly more stored water or a different type water supply. Also, partial protection may not be acceptable.

Therefore, I say that it is premature to ask whether there are systems available. Sure, there are systems available today that could be put in, but going back to what Rolf mentioned earlier, they're extremely expensive. (These would be 13 systems or modified 13 systems.) With the cost factor being primary, as far as user acceptance is concerned, I don't think you'd gain much outside of some tests that we would be very interested in seeing, by putting together a prototype system.

MR. H. SHAW: Comment, not a question. We have a program scheduled to fabricate a self-contained system and run certain tests with that system. Hopefully, that program will get underway by April. I think it's very similar to what Mike Bowman's asking about, the program and the test.

MR. BOWMAN: When do you expect to start? When will it be ready for field testing?

MR. H. SHAW: I haven't seen the formal proposal as yet so I don't know what the schedule will be. The prototype will not be a sophisticated system but, perhaps, a tank, a pipe, a sprinkler head, a sensing element. It will be tested on a standard test fire, a crib with a couch fire. That's where the program is going to start. We're going to find out if

two gallons can contain that fire, ten, fifteen, twenty, or three gallons, or less than two gallons. I would guess that you could probably be looking at a piece of hardware maybe at the end of June. It may only be the first piece.

MR. HENDERSON: Would you comment on the position of the NFPA Committee on the following possibility: Suppose there is developed a system which is only 70-80% effective. But the present 13-D sprinkler system is approximately 97% effective. What do you think your philosophy would be?

MR. SCHIRMER: Actually, Norm, you're talking about a long discussion. I wonder how many hours the committee spent on that one sitting around the table when 13-D was put together.

MR. HENDERSON: Are you thinking of the liability?

MR. SCHIRMER: What we felt in going with 13-D was that it was better to have a 90% system in, let's say 80% of the buildings than a 100% system in 0% of the buildings.

I can only speak for myself, and I sure can't speak for the committee, because there are as many ideas on that committee as there are fellows on it. I would say this: you must approach a much less than perfect situation. We do have to recognize that there are risks in this world and that sometimes we're going to have to take one of those risks. But I think we have to be at the same time very careful in defining what that system will and what that system will not do. We must also be assured that the public is aware of what that system will and will not do.

We certainly don't want to get into a situation where we tell an individual, you have a super duper system that really takes care of you, and two months later they have two members of their family dead.

The public is going to have to be aware that if a fire starts in an unsprinklered area, they may have problems. The public is going to have to be aware that if it does not get out of that dwelling within the water supply period -- if it's a stored water system -- that it's got trouble. Interestingly enough, both the performance standards and the 13-D right now have various levels of systems. I have no idea how the people on the committee would react to your question.

PERFORMANCE STANDARD FOR A LOW-COST RESIDENTIAL SPRINKLER SYSTEM

1. SCOPE, PURPOSE, AND LIMITATIONS

1-1* Purpose

This standard describes a low-cost automatic sprinkler system which will significantly reduce the loss of life by fire currently experienced in residences. It is expected that property damage will also be reduced.

1-2* Scope

This standard describes the requirements for the mechanical and performance properties of the sprinkler head itself. It also describes the requirements for the installation of the complete sprinkler system.

1-3* Limitations

1-3.1* This standard is intended to describe a sprinkler system which can maintain a tenable environment in the room of fire origin and elsewhere for a period of twenty minutes following operation of the sprinkler.

1-3.2 Persons in direct contact with flame may not benefit from the suppression portion of the sprinkler system, nor will persons suffering ancillary injuries such as those incurred falling downstairs while in the state of panic in reaction to the fire emergency.

1-3.3 This standard permits omission of sprinklers in certain areas in which fires are statistically unlikely to originate and in areas of low combustible loading. Fires starting in the former type of area will be uncontrolled except eventually by an outside agency.

2. SPRINKLER HEAD REQUIREMENTS

2-1 Glossary

2-2.1 Automatic Sprinkler - A device designed to open automatically by operation of a heat responsive releasing mechanism and to discharge water in a specific pattern over a designated area for the purpose of extinguishment or control of fire.

2-2.2 Upright Sprinkler - A standard sprinkler intended for installation in the upright position (deflector above the pipe).

2-2.3 Pendent Sprinkler - A standard sprinkler intended for installation in the pendent position (deflector below the pipe).

2-2.4 Dry-Type Sprinkler - A sprinkler that is designed to be free of water and, therefore, primarily intended for use where the sprinkler may be exposed to freezing temperatures. It may be upright, pendent, flush, or other type.

2-2.5 Flush-Type Sprinkler - A sprinkler intended for use where the piping is concealed and where only a minimum of the parts of the sprinkler project below the ceiling.

2-2.6 - Recessed Sprinkler - An assembly consisting of a standard pendent sprinkler installed in a holder so that the assembly can be partially recessed into a ceiling installation.

2-2.7 Plated Sprinkler - A sprinkler which has a factory-applied plating for decorative purposes.

2-2.8 Discharge Coefficient "K" - Coefficient of discharge - $Q = K\sqrt{P}$ where Q = flow and P = pressure. Q (gpm) = $K\sqrt{P\ (psi)}$.

2-2.9 Orifice - The opening in an automatic sprinkler body which determines the discharge coefficient.

2-2.10 Heat-Responsive Element - That portion of a sprinkler operating mechanism which breaks, melts, or otherwise functions on exposure to sufficient heat, thereby initiating the automatic operation of the device.

2-2.11 Operating Temperature - The temperature at which the heat-responsive element of a sprinkler operates when subjected to a 1°F per minute temperature rise in a liquid bath.

2-2.12 Sprinkler Time Constant - Time constant of the heat-responsive element, which is a measure of the thermal inertia of the element, determined in a standard test* by a recognized testing laboratory.

2-2.13 Leak Point - The pressure at which leakage of water around the orifice seat occurs at a rate greater than one drop per minute.

2-3 General Requirements

2-3.1 Performances

2-3.1.1 Sprinklers shall respond reliably and perform effectively under fire conditions by prompt actuation and by distributing water uniformly throughout their area of coverage. There shall be no significant amount of water discharged above the sprinkler.

2-3.1.2 Sprinklers shall remain intact, without leakage, throughout their service life and provide positive operation and release of all operable parts upon actuation.

2-3.2 Markings

2-3.2.1 The manufacturer's name or trademark and the model or type identification shall appear on the frame. The model or type

*Standard test still under development as of November 1977.

identification must correspond with the manufacturer's catalog designation and must uniquely identify the sprinkler as approved and also as compared to other types made by the same manufacturer.

2-3.2.2 The year of manufacture shall appear on a visible area of the sprinkler. Sprinklers manufactured in the first six months or last three months of a calendar year may be marked with the previous or following year, respectively, as the year of manufacture.

2-3.2.3 The operating temperature of solder type sprinklers shall be marked on the fusible element. The operating temperature of glass bulb type sprinklers shall be marked on a non-operating part or alternatively, the frame may be painted as shown in Table 2-4.2 and the temperature marked on an operating part.

2-3.2.4 If a manufacturer produces sprinklers with the same model designation at more than one factory, each sprinkler shall bear a distinctive marking to identify it as the product of a particular location.

2-4 Mechanical Requirements

2-4.1 Dimensions

2-4.1.1 Thread Size - Thread Size shall be 1/4, 3/8 or 1/2 inch and shall be NPT.

2-4.1.2 Orifice Size

a. The orifice size shall be 0.274 inch.

b. Other orifice sizes are permissable if the sprinklers demonstrate effective performance.

2-4.2 Temperature Ratings

Automatic sprinklers in their various ratings shall be designed for service where the maximum ambient air temperature, at the

point of installation does not exceed the values shown in Table 2-4.2. The color coding, where used, shall also conform to the temperature rating shown.

TABLE 2-4.2

TEMPERATURE RATINGS, CLASSIFICATIONS AND COLOR CODES

FUSIBLE ALLOY TYPES

Temperature Rating Range*	Max. Ambient Temperature	Temperature Classification	Frame Color Code
135 to 170°F	100°F	Ordinary	None
175 to 225°F	150°F	Intermediate	White
250 to 300°F	225°F	High	Blue

GLASS BULB TYPE

Temperature Rating	Max. Ambient Temperature	Frame Color Code
135°F	115°F	None
155°F	135°F	None
175°F	155°F	White
200°F	180°F	White

2-4.3 Strength of Parts

2-4.3.1 General - All parts used in a sprinkler assembly shall have adequate strength to maintain the integrity and reliability of the sprinkler throughout its expected life and service conditions. Specific requirements and tests designed to demonstrate this capability follow.

2-4.3.2 Assembly Load

a. The load which is applied to an automatic sprinkler frame due to the assembly of the operating parts is the assembly load and shall be measured. At least ten test specimens will be used to determine this value.

*Listed sprinklers shall have a specific temperature rating within the range.

b. Each test sprinkler is to be separately installed in a tension testing machine. The deflector end of the sprinkler will be considered the reference point. Each sprinkler will be activated and the resulting negative frame deflection measured.

c. The force, applied at a rate of 100 lb/min, required to return the deflector end of each sprinkler back to the reference point is the assembly load. The values obtained will be used to evaluate the frame strength as outlined in paragraph 2-4.3.3.

d. If the application of water pressure of 175 psi at the sprinkler orifice increases the assembly load by more than 10%, this additional load will be included as a part of the assembly load when evaluating frame strength and strength of the heat responsive element.

2-4.3.3 Frame Strength - Each of the sample sprinklers tested in accordance with Section 2-4.3.2 will be subjected to a frame load of twice the maximum.

2-4.3.4 Load on Heat-Responsive Element - The load exerted on the heat responsive element shall be measured to verify that it is within the manufacturer's design limits. For sprinklers having frangible bulbs, this load is the same as the assembly load, and a separate test is not required. For link and lever actuation mechanisms, the load will be determined by installing each test sprinkler in a link load testing machine. Force will be applied to the lever mechanisms until the link moves freely within its bearing seats. Ten samples will be tested. Separate tests may be required for sprinklers having other types of heat responsive elements.

2-4.3.5 Strength of Heat-Responsive Element - The heat responsive element shall have sufficient strength to withstand the maximum applied load throughout its expected life. Tests to verify compliance with this requirement will be conducted for soldered link assemblies and frangible bulbs as described below. Special tests will be developed for other types of heat responsive elements.

2-4.4 Operating Temperature

a. All fusible element sprinklers of a given model, type and temperature rating shall operate at their nominal release temperature subject to the following:

(i) The standard for sprinklers being tested shall not exceed the value calculated from the following relationship:

$$S_L(^oF) = .00\overline{3}X - 0.0\overline{26}$$

Where S_L = Limiting standard deviation

X = Nominal release temperature

(ii) No single sample tested shall deviate from the nominal release temperature by a value greater than three (3) times the limiting standard deviation (S_L) as determined above.

b. Samples of glass bulb sprinklers of a given model, type and temperature rating shall operate at their nominal release temperature subject to the following. The sample mean operating temperature may show a minus deviation from the nominal release temperature not to exceed 5.4^oF. The sample mean operating temperature may show a plus deviation from the nominal release temperature not to exceed 10.8^oF for sprinklers with a maximum nominal release temperature of 162^oF and not to exceed 14.4^oF for sprinklers with higher rated release temperatures.

(i) The sample standard deviation(s) shall not be greater than 9°F. The sample standard deviation (S) is calculated by the formula:

$$S = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}$$

Where $\bar{x}$ = Sample mean operating temperature

x_i = Individual operating temperature for each sprinkler tested

n = Number of sprinklers in sample tested

c. At least 20 samples of each temperature rating will be tested in a well-stirred liquid bath having a controlled temperature rise not exceeding 1°F per minute. The test results shall be as specified in paragraphs 2-4.4(a) and 2-4.4(b).

d. Water is used for testing sprinklers which have operating temperature ratings of 175°F or lower. Sprinklers having operating temperature ratings greater than 175°F will be tested in an oil having a flash point exceeding the test temperature.

2-4.5 Response

The sprinkler time constant shall not exceed 130 sec. at 5 ft./sec. nor be less than ...*

2-4.6 Leak Point and Hydrostatic Strength

a. An automatic sprinkler shall not leak when subjected to an internal hydrostatic pressure of 500 psi for one minute.

b. An automatic sprinkler shall also withstand, without rupture, an internal hydrostatic pressure of 700 psi applied for one minute.

c. At least ten sprinklers will be individually subjected

*To be determined

to a slowly rising hydrostatic pressure up to the point of observable leakage. Samples are to be filled with water and vented of entrapped air in preparation for this test.

d. The pressure will be gradually increased to 500 psi and held for one minute. During this phase there shall be no visible leakage from any sample.

e. Each sample will then be subjected to a gradually increasing hydrostatic pressure up to 700 psi. If leakage of one drop per minute occurs, between 500 and 700 psi, that pressure will be recorded as the "leak point". The test is then to be continued up to 700 psi and held for one minute. There shall be no rupture of any sample.

2-4.7 Impact Resistance

a. An automatic sprinkler shall have adequate strength to withstand impacts associated with handling, shipment and installation without deterioration of its performance or reliability.

b. To verify compliance with this requirement, five samples will be tested by dropping a weight onto the deflector end of the sprinkler along the axial centerline of the waterway. The kinetic energy of the dropped weight at the point of impact shall be equivalent to a weight equal to that of the sprinkler dropped from a height of 3 ft. Following this test, each sprinkler will be visually examined for any fracture, deformation or other deficiency. If none is detected, the sprinkler will be subjected to a 500 psi hydrostatic pressure test for one minute. Each sample shall withstand this pressure without leakage.

2-4.8 Minimum Operating Pressure

a. An automatic sprinkler shall respond with positive operation and release of all applicable parts at a service pressure of 5 psi.

b. An exception to the minimum operating pressure requirement is made for dry upright type sprinklers. These sprinklers must operate properly and reliably at 10 psi or less. At least five samples of the longest length manufactured will be tested to determine compliance with this requirement. All samples shall operate at or below 10 psi.

2-4.9 Hang-up of Parts (Lodgements)

a. Operating parts of an automatic sprinkler shall be completely ejected upon actuation and not become lodged in such a manner that the distribution of the sprinkler is adversely affected.

b. At least ten samples will be tested at each of three or more water supply pressures between 5 and 175 psi. If a hang-up of any part is observed in more than 3% of the samples tested, a special investigation will be conducted to determine the susceptibility of the sprinkler to this problem.

2-4.10 Maximum Ambient Temperature

a. An automatic sprinkler shall withstand an exposure to its maximum allowable ambient temperature for a period of 90 days without evidence of weakness or failure.

b. To verify compliance with this requirement, ten samples of each temperature rating will be tested at 500 psi, then subjected to their maximum allowable ambient temperature for 90 days. After this exposure, each sample will be tested to determine its leak-

point. No sample shall leak below 500 psi. Five samples will then be tested for operating temperature as specified in Section 2-4.4. Each test sprinkler shall operate within the stated temperature limits.

c. At the manufacturer's option, additional samples may be supplied to provide an early indication of possible failure. These samples will be removed from the test oven after 30 days (or some other interval specified by the manufacturer) and tested as described above. However, determination of compliance with the maximum ambient temperature requirement will be based on results of the 90-day test.

2-4.11 Effect of Platings

Application of platings can affect the operating temperature, sensitivity or distribution of a sprinkler. Plated sprinklers will be tested to determine that they meet the distribution requirements of paragraphs 2-4.13.

2-4.12 Discharge Coefficient

The discharge coefficient shall be 1.95 $\pm$5% at 10 psi. Other discharge coefficients are permissible if the sprinklers demonstrate effective performance.

2-4.13 Sprinkler Distribution

To be determined.

2-4.14 Lateral Discharge Effects ("Cold Soldering")

a. An automatic sprinkler, discharging water at a service pressure of 100 psi, shall not prevent the operating of a second ordinary temperature rated automatic sprinkler having frame arms parallel to the first and located 6 ft distant on an adjacent pipe line in the same horizontal plane.

b. An ordinary temperature rated sprinkler will be installed on piping 6 ft (center to center) from a second sprinkler which is to be open. The sprinklers will be on separate parallel pipe lines, with the frame arms parallel to the pipe line. The sprinkler deflectors will be 22 in. below a flat ceiling. Water will be discharged from the open sprinkler at a service pressure of 100 psi. Under this condition, the closed sprinkler will be exposed to the heat and flame from a 1 ft. sq. pan, 4 in. deep, containing 1 pint of n-heptane, with the top of the pan located 6 in. below the heat responsive element of the sprinkler. The test will be repeated with the sprinkler deflectors located 6 in. and 14 in. below a flat ceiling. The test sprinkler is to operate before the fuel is consumed.

2-4.15 Special Type Sprinklers

a. Dry Types - Dry type sprinklers shall meet the distribution requirements for standard sprinklers.

b. Flush Types - Flush type sprinklers shall meet the distribution requirements for standard pendent sprinklers, except that a 10% reduction in the required collections will be allowed.

c. Recessed Types - Recessed type sprinklers shall meet the distribution requirements for standard pendent sprinklers.

2-5* Fire Test Performance Requirements

2-5.1* Standard Fire Test Conditions

2-5.1.1* Fire Test Room Dimensions and Furnishings, Furnishing Placement, Sprinkler Location, and Carbon Monoxide and Temperature Measurement Points shall be as in Figure 2-5.1.1.

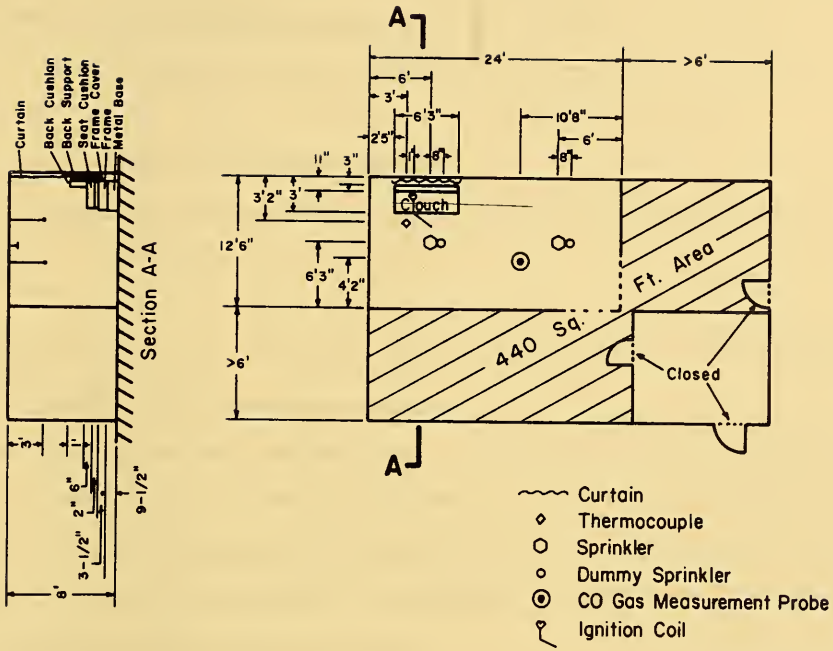


Figure 2-5.1.1

2-5.1.2 Furnishings Specifications

a. Couch

Base - 9 1/2 inch high metal frame

Support Frame - Metal strips gridded on a 75 inch by 33 inch frame with 3 1/2 inch high sides of 3 1/4 inch thick eastern pine.

Frame Cover - A 75 inch by 33 inch by 2 inch high urethane foam slab with a density of 1.2-1.3 lb/ft^3.

Cushion (seat) - A 75 inch by 33 inch by 6 inch high urethane foam slab with a density of 1.2-1.3 lb/ft.^{3}

Cushion (back) - A 75 inch by 8 inch by 12 inch high urethane foam slab with a density of 1.2-1.3 lb/ft.^{3}

Cover Material - Frame cover and cushions wrapped around with (ends exposed) 85-90% cotton and 10-15% polyester blend corduroy fabric with 8 thick and thin wales in. The material should weigh about 9.6 oz/yd.^{2}

b. Carpet - 100% nylon two ply, that extends 12 inches beyond couch on all sides.

c. Drapes - 50% Fortrel polyester and 50% cotton blend that weighs 4.6 oz/yd.^{2}

d. Room Construction

1. Walls - U.S. Gypsum 5/8 in firecode.

2. Drop Ceiling - Armstrong 915 textured Fire Guard Fashiontone vinyl latex finish.

2-5.1.3 Ventilation

There shall be no mechanical ventilation nor openings in the room walls, ceiling or floor.

2-5.1.4 Ignition Procedure

A 50 watt heating coil (immersion heater rated 300 watts at 110 V-KDK Japan or equivalent) spread open to 3 in. and placed 18 in. from the end of the couch under the front edge of the back cushion. The coil should be removed after 20 minutes of exposure.

2-5.1.5 Relative Humidity

Relative humidity should be within the range of 40-80%.*

2-5.1.6 Room Temperature

Room Temperature should be in the range of 50-90°F.*

2-5.2 Carbon Monoxide Generation

A curve as shown in Figure 2-5.2 shall be generated from data gathered from the carbon monoxide monitor at the location shown in the Figure 2-5.1.1 during the fire test. Integrated area "A" (Figure 2-5.2) shall not exceed 48,000 ppm-minutes. Instantaneous carbon monoxide levels shall not exceed 3000 ppm.

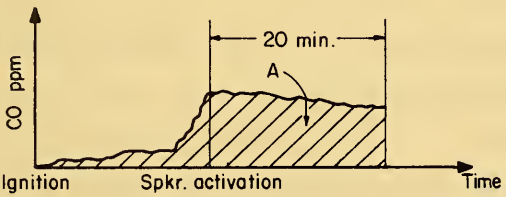


Figure 2-5.2

2-5.3 Temperature

The temperature at the location shown in Figure 2-5.1.1 during the entire test up to 20 minutes past the time of sprinkler operation shall not exceed 160°F for more than ten seconds.

*Ranges may be revised based on results of future testing.

2-5.4 Sprinkler

Only one sprinkler shall operate during the test.

3. SYSTEM INSTALLATION REQUIREMENTS

3-1 General

Low-cost residential sprinkler systems shall be installed in accordance with the following requirements. Sprinklers shall be listed by a nationally recognized testing agency.

3-2 Pipe

Pipe may be PVC (national specification to be determined*) where concealed behind a 1/2 hour rated ceiling or wall, or copper conforming to Table 3-1.1.1 in NFPA 12, "Installation of Sprinkler Systems".

3-3 Joints

3-3.1 PVC pipe shall be joined to other components by solvent-cement in accordance with the manufacturer's instructions or with screwed joints. If screwed joints are used, the pipe wall thickness must conform to at least standard Schedule 80.

3-3.2 Copper pipe shall be joined by soldering in accordance with standard plumbing practice.

3-4 Fittings

3-4.1 Fittings for PVC pipe shall conform to (national specification to be determined).

3-4.2 Fittings for copper pipe shall conform to Table 3-12.1.1 in NFPA 13, "Installation of Sprinkler Systems".

3-5 Equivalency

Pipe, joints or fittings meeting or exceeding the requirements of 3-2, 3-3, or 3-4 shall be acceptable.

*PVC specification not yet clearly determined. Will probably reference one or more of ASTM specifications D-1785, D-2241, D-2466, D-2564, or D-2855.

3-6 Pipe Hangers

Pipes shall be supported in accordance with good plumbing practice.

3-7 Fire Alarms

3-7.1 Fire alarms shall be provided

3-7.2 Fire alarms in decreasing order of preference are:

3-7.2(a) Signal sent to the public fire department, as well as to a loud local alarm.

3-7.2(b) Signal sent to a reliable central station service, as well as to a loud local alarm.

3-7.2(c) (Signal sent to a loud local alarm.)

3-7.3 Local alarms shall be audible directly outside sleeping areas and outdoors.

3-7.4 Fire alarms for sprinkler systems having the water supply from a separate connection to the incoming public water supply shall be initiated by means of a flow or pressure switch in the riser, downstream of the check valve required in paragraph 3-11.

3-7.5 Fire alarms for sprinkler systems having the water supply from interior domestic piping shall be initiated by smoke or heat detectors in the sprinklered areas.

3-7.6 Unsprinklered areas shall be provided with smoke or heat detectors arranged to initiate the firm alarm.

3-8 Areas to be Sprinklered

3-8.1 Bedrooms, living rooms, kitchens, family rooms, and utility rooms shall be sprinklered. See also 3-9.2.

3-8.2 If separated from the areas in 3-8.1 by 1/2 hour rated partitions, attics, basements, garages and storerooms need not be sprinklered. Otherwise, these areas shall be sprinklered on a wet system if heated. If the area is not heated and exposure to freezing temperatures is possible, dry pendent sprinklers or a dry or non-freeze system shall be installed in accordance with Chapter 5 of NFPA 13 (Installation of Sprinkler System). All operating characteristics of dry pendent assemblies shall be equal to that of standard sprinklers of the same rating and orifice size.

3-8.3 Closets and bathrooms need not be sprinklered.

3-9 Water Supplies and Duration

3-9.1(a) The water supply shall be capable of supplying at least 6 gpm at a discharge pressure of at least 8 psi through the hydraulically most remote sprinkler for a wet or dry pendent sprinkler non-freeze system. For a dry system, the supply shall be capable of supplying the above flow and discharge pressure to two sprinklers simultaneously.

3-9.1(b) If the sprinklers are capable of spacing greater than those specified in 3-12.1, 3-12.2, and 3-12.3, the water supply necessary to achieve those spacings shall be available.

3-9.2 The water supply shall be capable of supplying the required flow for at least 20 minutes.

3-10 Pipe Sizes

The pipe sizes shall be such that the water supply required in 3-9.1 is available at the hydraulically most remote sprinkler for a wet or non-freeze system or pair of sprinklers for a dry system.

3-11 Water Supply Arrangement

The water supply connections to the sprinkler system may be directly from convenient domestic water piping, or may be a separate piping system. If the latter, the connection to the incoming water supply piping from the public main should be downstream of the main domestic system shut-off valve, and a rubber-faced check valve should be provided in the sprinkler system connection.

3-12 Sprinkler Spacing

3-12.1 Sprinklers shall be arranged so that each covers no more than 150 sq ft of floor area.

3-12.2 The maximum perpendicular distance from a sprinkler to a wall is 7 ft.

3-12.3 The maximum distance between sprinklers is 12 ft.

3-12.4 Larger sprinkler spacings are permissible if the sprinklers demonstrate effective performance at those spacings. (See 3-9.1(b))

3-13 Back Flow Prevention

The local health authority may require back-flow prevention. Pressure loss associated with the required equipment shall be considered in the hydraulic calculations.

3-14 Sprinkler Temperature Rating

The sprinkler temperature shall be selected to correspond with the maximum expected ambient temperature. (See Table 2-4.2)

A-1.1 Residential fires in the U.S.A. annually take 6000 to 7000 lives. Any reduction in this number is desirable. A sprinkler system can have a major impact on reducing life loss in these fires; various studies have indicated from 50% to 91% reductions. The inclusion of an alarm to indicate a fire condition in itself can only have a contributory effect; awareness of others of the fire increases the chance of help arriving.

A-1.2 The intent of this standard is that it be applied primarily to residences under construction. This is so that the piping may be concealed. Concealment is important for aesthetic reasons, and even for acceptance of the system by residential occupants. The system may be far more economically installed while the residence is under construction, the difference between installation in existing versus new urban construction being 50% according to one study. The sprinkler head contemplated by the standard does not currently exist commercially. Other components such as piping do, and may therefore be described by referring to the nationally-recognized specification to which they are made.

A-1.3.1 There has been much discussion among experts as to what constitutes a tenable environment. Among the many problems is that older or very young people or those in poor health are less able to withstand environments made hostile by toxic gases and high temperature. This standard recognizes these problems and has taken a conservative approach in setting maximum acceptable levels on the various controllable environmental characteristics. Twenty minutes is considered ample time for response by the public fire department or by others to aid in the removal of the incapacitated person(s) from the area of danger. This may

not be strictly true in rural areas where distances to be covered by rescuers are often greater, and roads may be difficult to traverse in winter weather. While not ignoring the rural fire problem, this standard recognizes that the bulk of the fire death problem is in urban or suburban areas and focuses there.

A-2.5 There are no minimum smoke obscuration levels specified in this standard. This is because the sprinkler system contemplated is expected to save the lives of persons without any action on their part. Their ability to see is, therefore, not a factor.

A-2.5.1 This room simulates a living room. Communication with other areas of the dwelling is also simulated.

A-2-5.1.1 The carbon monoxide monitoring position was chosen since air turbulence is likely to be less there than elsewhere. Higher carbon monoxide levels are thus more likely there. This is thus a more conservative location. The eye level carbon monoxide and temperature locations are also conservative in that a person remaining in the room would likely be prone or seated, i.e., below eye level: carbon monoxide and temperature levels are higher at higher elevations.

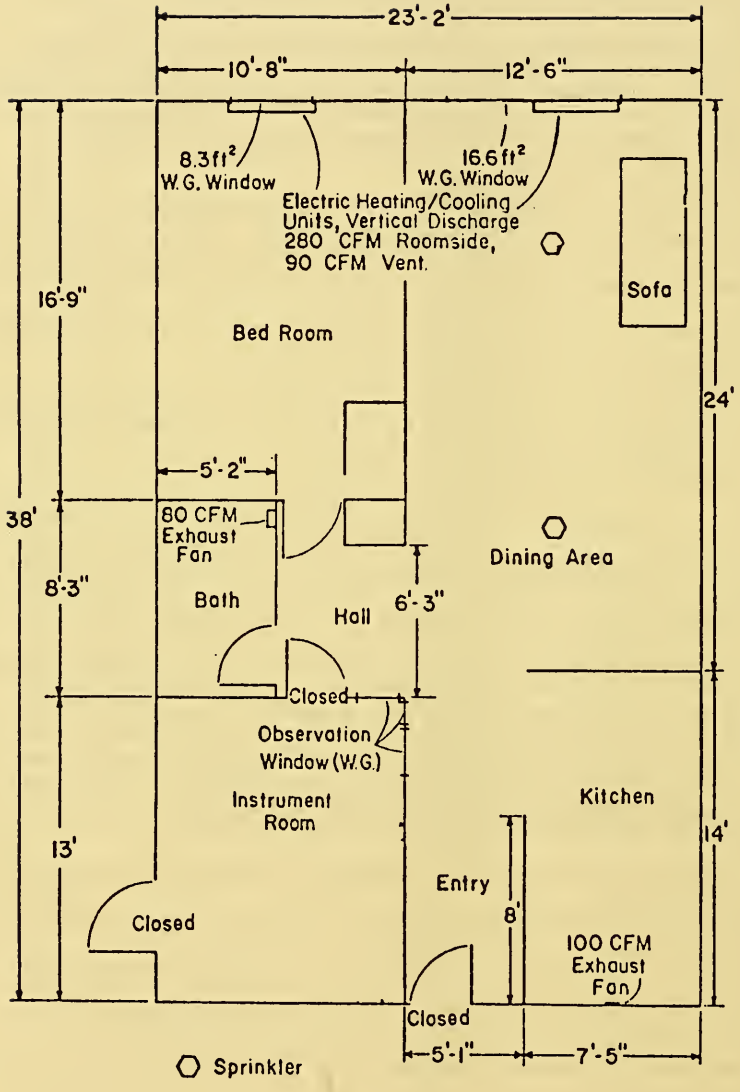


FIGURE 1 TEST APARTMENT FLOOR PLAN

OBJECTIVE:

TO DEVELOP SPRINKLER SYSTEMS WHICH REQUIRE SIGNIFICANTLY LESS WATER BUT STILL PROVIDE ADEQUATE PROTECTION FOR BOTH LIFE AND PROPERTY

APPROACH:

DETERMINE THE REQUIRED SPRINKLER DISCHARGE CONDITIONS IN REALISTIC FIRE TESTS

SPRINKLER DISCHARGE CONDITIONS:

WATER DISCHARGE RATE
WATER DISTRIBUTION
DROP SIZE

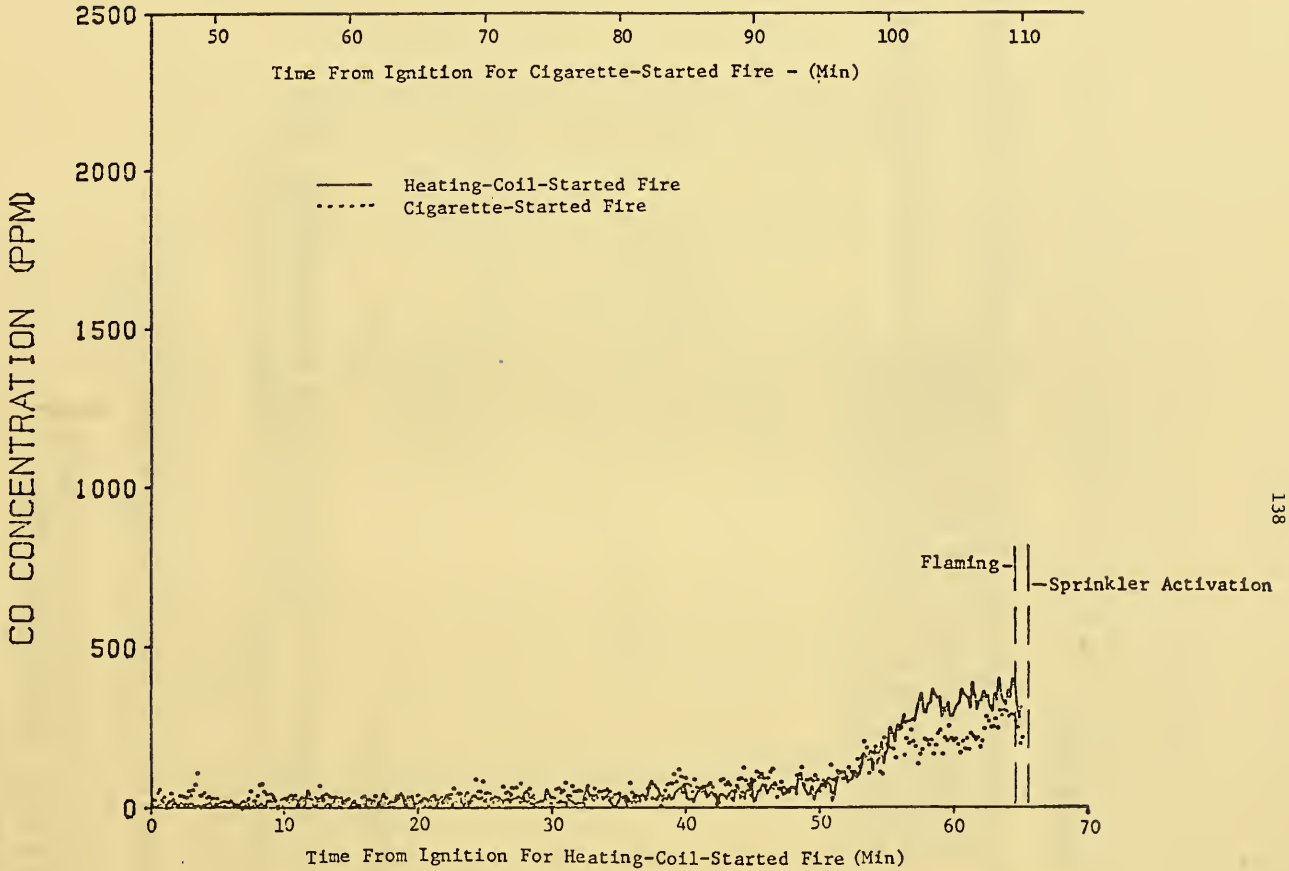


FIGURE 3. COMPARISON OF CO CONCENTRATION AT EYE LEVEL IN LIVING ROOM BEFORE SPRINKLER ACTIVATION FOR CIGARETTE-IGNITION FIRE AND HEATING-COIL-IGNITION FIRE (Location:62-in.Above Floor, 53 in. From West Wall and 13.33 ft.From North Wall)

SPRINKLER DISCHARGE VARIABLES

Sprinkler Discharge Pressure Δp (psig)		Sprinkler Orifice Diameter, D, (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	Water Discharge Rate W (gpm)	15.0	8.8	6.0				
	Application Density (gpm/ft^2)	0.10	0.059	0.040				
28.5	Water Discharge Rate W (gpm)			11.5	7.0	3.9		
	Application Density (gpm/ft^2)			0.077	0.047	0.026		
88.5	Water Discharge Rate W (gpm)					6.8	4.7	3.4
	Application Density (gpm/ft^2)					0.045	0.031	0.023

CRITERIA FOR EVALUATING CO HAZARD

1. Maximum CO concentration at eye level < 3000 ppm

2. Integrated value of CO concentration over the exposure period < 43,000 ppm-min

TABLE II

CO CONCENTRATION (ppm) AT EYE LEVEL

Sprinkler Discharge Pressure Δp(psig)		Sprinkler Orifice Diamater, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	CO at t_f	360	320	330				
	CO at t_s	320	240	250				
	CO at t_s + 5 min	230	320	570				
	CO at t_s + 10 min	150	250	1180				
	CO at t_s + 20 min	110	230	1440				
28.5	CO at t_f			340	310	-		
	CO at t_s			110	210	-		
	CO at t_s + 5 min			1400	750	-		
	CO at t_s + 10 min			2130	1650	-		
	CO at t_s + 20 min			2010	1850	-		
88.5	CO at t_f					330	300	-
	CO at t_s					280	280	-
	CO at t_s + 5 min					335	740	-
	CO at t_s + 10 min					420	1320	-
	CO at t_s + 20 min					370	1730	

Note: t_f - time of flaming from ignition

t_s - time of sprinkler activation from ignition

TABLE III

CUMULATIVE CO CONCENTRATION (ppm-min)

Sprinkler Discharge Pressure Δp (psig)		Sprinkler Orifice Diameter, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	CO to t_f	4,650	4,370	6,720				
	CO to t_s	5,050	4,680	7,030				
	CO to t_s + 5 min	6,420	6,200	8,830				
	CO to t_s + 10 min	7,430	7,570	13,780				
	CO to t_s + 20 min	8,980	9,870	27,080				
28.5	CO to t_f			4,120	4,830	—		
	CO to t_s			4,520	5,270	—		
	CO to t_s + 5 min			7,550	6,480	—		
	CO to t_s + 10 min			17,030	11,470	—		
	CO to t_s + 20 min			39,780	28,920	—		
88.5	CO to t_f					4,780	5,820	—
	CO to t_s					5,100	6,080	—
	CO to t_s + 5 min					6,505	8,030	—
	CO to t_s + 10 min					8,080	13,720	—
	CO to t_s + 20 min					11,700	29,650	—

Note: t_f - time of flaming

t_s - time of sprinkler activation

TABLE IV

GAS TEMPERATURE AT EYE LEVEL (F°)

(4 ft 6 in. from floor, 3 ft from north wall)

Sprinkler Discharge Pressure Δp (psig)		Sprinkler Orifice Diameter, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	T_{ei}	70	75	84				
	T_e	150	144	147				
	T_e'	80	76	89				
28.5	T_{ei}			68	71	72		
	T_e			137	147	156		
	T_e'			81	85	85		
88.5	T_{ei}					74	76	79
	T_e					137	159	131
	T_e'					83	89	92

Note: T_{ei} - gas temperature at start of test

T_e - gas temperature at time of sprinkler activation

T_e' - gas temperature at 1 min after sprinkler activation

SPRINKLER DISCHARGE VARIABLES

Sprinkler Discharge Pressure Δp (psig)		Sprinkler Orifice Diameter	
		0.274	0.137
8	Water Discharge Rate (gpm)	6.0	
	Application Density (gpm/ft^2)	0.040	
28.5	Water Discharge Rate (gpm)	11.5	
	Application Density (gpm/ft^2)	0.077	
88.5	Water Discharge Rate (gpm)		4.7
	Application Density (gpm/ft^2)		0.031

TABLE VI

CEILING TEMPERATURE DIRECTLY ABOVE THE IGNITION POINT (°F)

Sprinkler Discharge Pressure Δp(psig)		Sprinkler Orifice Diameter, D (in.)						
		0.438	0.329	0.274	0.219	0.164	0.137	0.110
8	T_c	283	333	306				
	T_c'	173	203	219				
	T_{ci}	70	72	84				
	$(T_c - T_c')/(T_c - T_{ci})$	0.52	0.50	0.39				
28.5	T_c			264	276	311		
	T_c'			172	224	216		
	T_{ci}			70	70	72		
	$(T_c - T_c')/(T_c - T_{ci})$			0.47	0.25	0.40		
88.5	T_c					265	337	262
	T_c'					186	208	209
	T_{ci}					77	79	84
	$(T_c - T_c')/(T_c - T_{ci})$					0.42	0.50	0.30

Note: T_{ci} - Ceiling temperature at start of test

T_c - Ceiling temperature at time of sprinkler activation

T_c' - Ceiling temperature at 1 min after sprinkler activation

MR. HARRY SHAW: We've arrived at the point in the program in which we will begin to examine the Performance Standard for a Low-Cost Residential System developed by Factory Mutual Research under the project leadership of Graham Clarke. We have mailed copies of the specification to all attendees. Distributed to you today is the latest revision. We have a panel from Factory Mutual who are ready to discuss the performance specification with you, respond to your questions, and solicit your suggestions for revision. Heading the panel is Ray Praetz. With him are Graham Clarke, Cheng Yao, Gunnar Heskestad, and Hisang Chang Kung. The rostrum is yours, Ray.

MR. PRAETZ: The performance standard in large was the output of considerable effort on the part of Graham Clarke. I'd like to start by having Graham say a few words to you.

MR. GRAHAM CLARKE: The performance specifications that you have in front of you are not cast in stone by any means. They're entirely subject to change. Hopefully some of the input for that change will come from this group this afternoon. It's important to realize that this performance spec applies to sprinkler systems for new construction only. We are, by definition, dealing with a low-cost sprinkler system. That's the goal. And such cannot be achieved in existing construction using this performance spec. Having made those two points, I'll turn it over to Ray again.

MR. PRAETZ: Residential fires in the United States annually take 6000 to 7000 lives. We've already had considerable discussion, by others, as to the extent of lives and injuries, and the potential beneficial effects of detectors and suppression systems. Some of those studies have indicated that if all residential areas were provided with ordinary sprinkler systems, the death toll could be reduced by 50 to 91 percent. The technology currently exists by which effective sprinkler systems can be installed in residences. Such systems, however, require water supplies often beyond

those normally available in residences. In addition, large piping, an inch to an inch and a half, is necessary to distribute the water. These two factors combine to make these two systems economically unattractive.

As a result, sprinkler systems are very rarely installed in residences; the desired reduction in life-loss is thus not achieved. The purpose of this investigation is to develop a low-cost residential sprinkler system, and thereby encourage it's use. Others -- and I must, at this point, indicate that the specification standard that we have generated is largely based on the results and efforts on the part of Battelle, Mr. Henderson, Mr. Schirmer, Mr. Halpin, people at APL and Johns Hopkins, Mr. Jensen, Dr. Kung, Dr. Heskestad, Mr. Yao, and particularly Mr. Clarke.

As a result of the information that has been supplied by these people, and of experiments that were conducted with various water discharge services, we have developed a sprinkler head which appears to be an attractive candidate to achieve an optimum or an effective system, suitable for use with limited water supplies.

There have been studies, as previously mentioned, analyzing systems cost, public acceptance, union jurisdiction problems, and the like. The overall program goal is intended to provide a sprinkler system performance specification using the data from all sources, so that a particular and effective system may be described. Users could, with these performance specifications install effective, low-cost sprinkler systems. The procedure for producing performance specifications involved studies, of reports and documents produced by others, involving related contract work; and the application of considerable judgement.

The result of those efforts is the draft of performance specifications for a low-cost residential sprinkler system, which all of you have. This draft may be considered as including two major elements: a set of performance criteria for the sprinkler head itself; and a set of rules governing the installation of the system, using that sprinkler head.

Sprinkler head criteria require a standardized fire test, designed to demonstrate whether a candidate sprinkler head, together with a specified water supply, is capable of maintaining an environment considered to be tenable in the test area for the duration desired.

Input during the review period of the above described draft is needed to further refine the performance specification. The draft will then be revised, and hopefully, will then be a usable tool in reaching the goal of reducing loss of life from residential fires. Further research should be then considered so that performance specifications could be extended to describe the low-cost, effective sprinkler system suitable for installation in existing residences, and to supplement the information already placed in the specifications that we have.

At this point, I would like to go directly to the specifications. I felt that any visual display of the words in these specifications would not really be very legible. So I'd ask you to follow along with me, using your copy of the specifications. At the end of each section, I will hesitate. If you have any questions or comments, we earnestly solicit them.

Let us turn to the page headed, "Performance Standard for a Low-Cost Residential Sprinkler; Item 1-1, asterisk, entitled, "Purpose." This

standard describes a low-cost automatic sprinkler system which will significantly reduce the loss of life by fire currently experienced in residences. It is expected that property damage will also be reduced.

The Scope: This standard describes the requirements for the mechanical and performance properties of the sprinkler head itself. It also describes the requirements for the installation of the complete sprinkler system.

Limitations: this standard is intended to describe a sprinkler system which can maintain a tenable environment in the room of fire-origin and elsewhere for a period of 20 minutes, following the operation of the sprinkler.

MR. DOSEDLO: Lee Dosedlo, Underwriters Laboratory. I think a statement of this nature leaves all the parties involved quite open to a lot of legal liabilities. This standard is intended to maintain a tenable environment in the room of fire-origin for 20 minutes. Unless you clearly define all the combustible materials in that room of fire origin, and also the source of that fire -- on the backside of a couch or if a mattress or a bed that the water can't even reach -- I don't think you should be saying that it will maintain a tenable environment for 20 minutes. Because if someone installed one of these systems, exactly in accordance with this standard, and a loss of life resulted, wouldn't a statement like that cause a lot of legal liabilities?

MR. CLARKE: I'd like to respond to that. You're talking about a completely separate problem. We've got two problems here. One is to produce a document which will describe a low-cost residential sprinkler system. The other is the real problem which you just described as the

liability aspect of it. They may be mutually exclusive problems. If we handle one, we may create the other problem. I think -- I'm not being facetious, but I really think -- that if we hesitate to move until we're positive of our legal grounds, then we may not move at all.

MR. DOSEDLO: I'm 100 percent in favor of a sprinkler of this type. I just think that a statement of this type doesn't belong in this standard. To say that you're guaranteeing that you can maintain a tenable environment for 20 minutes when the room can involve hundreds of different combustible materials igniting in many different manners is a precarious matter. I think one test, one situation can't cover all that.

MR. CLARKE: We are trying to describe a sprinkler system that will save lives. I don't think any purpose would be served by a statement saying this may or may not save lives.

MR. DOSEDLO: I just think you should leave the statement out. It would still be a low-cost, residential sprinkler without that statement.

MR. SHAW: Tony Shaw. Doesn't the word, "intended," sort of leave it open-ended, not guarantee it? It certainly leaves you an out, by using the word "intended." Its intent is such and such, thus and so; it's certainly not a guarantee.

MR. PRAETZ: Perhaps we have to make a statement giving the parameters of what our intent is. I think we all agree, basically, that this is what our intent is. As a separate issue, we should perhaps look into the legal liability of what type of statement. Would that be agreeable to you?

MR. DOSEDLO: It's just a suggestion.

MR. YAO: If you can take these words out, you make the whole standard meaningless. The 20 minutes are important to a tenable environment.

DR. CLARKE: Fred Clarke, Center for Fire Research. Maybe I can help you on this. The fact that we're talking about a draft standard here without any legal standing one way or the other isn't going to impact anybody's liability until it is adopted. Standards in general are not going to afford manufacturers this protection, whether they meet them or not, except in grounds for negligence. Once an action is enjoined, you're already talking about the apparatus having failed, and the argument would center around why it failed, not whether or not that standard may or may not have been adequate. In short, if you're still concerned about it, you might want to say the rationale behind the standard is to provide protection. There's certainly nothing wrong with that. I question whether or not we're really concerned about writing a standard that describes a low-cost automatic sprinkler system or whether we're writing a standard that sets a performance criterion that still protects the loss of life in residences, and can be met by a low-cost automatic sprinkler system. I think it's an important system. The purpose of the standard should be to provide performance criteria which can be met by a low-cost system.

MR. PRAETZ: The point is well taken.

MR. HENDERSON: I'm wondering what the rationale for the 20 minute time is, particularly, since in the standard you talk about alarms, and how that's tied to fire service. Where did the 20 minutes come from?

MR. CLARKE: It was a judgement. We had to pick a number. A number was necessary. The 10 minutes, which I think is in 13-D, I felt to be too short. I don't think that in a lot of cases we can reasonably expect the fire department to be on the scene in 10 minutes. Twenty minutes, I think, gives a more comfortable margin.

MR. BARNETT: Charley Barnett, Automatic Sprinkler. Do I understand the gentleman's comments? Is this to be a performance standard, and not one for installation? Are you omitting your requirements for installation?

MR. PRAETZ: No, the requirements for installation will still be in.

MR. BARNETT: My question is, then, why do you want to combine the two?

MR. PRAETZ: Performance and installation into one standard? In order to establish the type of sprinkler that is acceptable for use in this type of an application. And also, to tell people how to do it.

MR. BARNETT: That's a departure from existing standards.

MR. PRAETZ: It may be. The type of sprinkler that has been developed is also a departure.

MR. GRAHAM CLARKE: What we were contracted to deliver is a package, and this is what we delivered. It admittedly is different from the average NFPA standard.

MR. HAMMERMAN: Dave Hammerman, Maryland Fire Marshal's Office. My understanding of the phraseology of the Purpose in the standard is to specify a level of performance. In other words, saying the purpose of the standard is to specify. And on the other hand, the Scope, rather than describe, seems to provide. And I'm a bit concerned that the provisions under Limitations are telling me that if untenable limits are reached prior to the operation of that sprinkler, that the system is a failure. The standard seems to be speaking to the point where the sprinkler operates. Now, does that imply that the spinkler will operate before untenable conditions?

MR. PRAETZ: That's correct.

MR. HAMMERMAN: It shouldn't say that.

MR. CLARKE: Dave, you're right; it could stand some rewording to make that clear.

MR. PRAETZ: It would start from time zero.

MR. HAMMERMAN: Also, while I have the opportunity to talk, in 1-3.3, the last sentence of that paragraph, I find it difficult to say emphatically that fires starting outside of an area that has no sprinkling protection will, in fact, be absolutely uncontrolled. There should be a statement saying that the system, by its very nature, would have a degree of control over an area where fire starts that isn't provided with absolute protection. In other words, there will be, to some degree, control similar to those tests of a sprinkler in a corridor. Even if the bedroom is not sprinklered, there is a degree of control to persons elsewhere than in the bedroom. So, I'm suggesting perhaps a more positive wording within the Limitations.

MR. PRAETZ: Do you have a suggestion?

MR. HAMMERMAN: At the moment I would just strike the last sentence.

MR. PRAETZ: We'll consider that. I would ask that we try to follow in sequence, so we avoid confusion. Right now the only point we've gone up to is 1-3.1.

MR. FOEHL: Foehl of Copper Development. I'd like to go back to 1-3.1 on the 20 minutes aspect and ask the question: Does the 20 minutes presuppose that the sprinkler operation is the alarm-transmitting mechanism?

MR. CLARKE: John, that's right - unless the fire orginates in an unsprinklered area, in which case the detector, which is called for later on in the spec, will be transmitting the mechanism.

MR. PRAETZ: It could also be a detector in an area where the sprinklers are fed by domestic piping.

MR. HENDERSON: Norm Henderson, Battelle. Is it our purpose here to worry over each word and all of the phraseology in detail?

MR. PRAETZ: In the interest of not getting tied up too much with time and phraseology, I would ask that we try to direct your comments to what is considered to be errors or factors in which there's real disagreement.

MR. PIETRZAK: In this regard, would it be possible if we could provide someone more specific written comments later on? I have minor problems here and there that I don't think should be handled in the context of this meeting. For example, Residence. What do you mean? Does that mean apartments versus single-family dwellings? These are the kinds of things to be discussed or at least provided as written sommunications to you to think about.

MR. PRAETZ: Any written comments regarding phraseology or of the nature you mention might be given to us through Harry Shaw. I would think that there would be some limited period of time within which Harry might want you to direct those comments.

MR. PIETRZAK: What would that time be?

DR. JOSEPH CLARK: The sooner the better, certainly, within two weeks is desirable.

MR. BRYAN: John Bryan, University of Maryland. Under Limitations, I'd like to see either one additional section or two additional sections. I think you should include the fact that you are limiting the Standard to new construction, a matter which I don't see in the specifications, though it was in the covering letter. It should also be indicated, I believe, that you're excluding the side wall sprinkler head from your limitations, though that's spelled out in performance. I would like to suggest that you add under the Glossary the definition of Residential. If you mean by the title, "Low-Cost Residential Sprinkler Systems" -- so you define what sort of residential occupancy you're talking about. Also under Glossary, if you could put in your definition of "untenable environment" -- we saw from your test results you were talking about solely CO concentration. Whatever you mean by that, if you would just put it in the Glossary, I think it would improve the document.

MR. PRAETZ: The definition of residential, as you point out, is appropriate. We discuss the environment later on in this document -- we go into considerable depth on what a tenable environment is and what the parameters of a tenable environment are, when we set up out test criteria. These criteria really define what is a tenable environment from the point of view of this document. We define it perhaps better than it would be briefly defined in the Glossary.

MR. KUCHNICKI: Dick Kuchnicki, National Association of Home Builders, on paragraph 1-3-1. The 20 minutes also bothers me. If you are assuming that 20 minutes is based on the fact that it takes that much time for the fire department to get there, I think somewhere there should be a statement to that effect. Also, I think that while the 13-D standard uses 10 minutes, I guess, because that estimates the time it takes to evacuate the house -- at least that's my understanding -- it seems to me that built somewhere in the Standard we should probably have some levels of performance. One of the levels would be the 10-minute level of what it takes to get out for the purposes of life safety. The second level would be the 20 minutes, which could be applied more toward saving the property rather than life support.

MR. PRAETZ: The 20 minutes, I think, is perhaps somewhat on the conversative side. That's what we're trying to imply. I think that the 20 minutes should allow a person in almost any condition sufficient time to discover the fire and get out. We've discussed previously the problem of alcohol and of people who are not really mobile. The 20 minutes provides an outside parameter.

MR. KUCHNICKI: I don't think you have enough data to say for sure whether 20 minutes is conservative.

MR. YAO: Supposing somebody cannot get out on his own; hopefully, 20 minutes might be sufficient to be rescued.

MR. TESTA: Bill Testa. I take it that the 20 minutes will infer that that is also the water supply limit. I think that, too, should be in the definition.

MR. PRAETZ: I think that is a definition that is specified in the water section of the Standard. I don't know that we'd want to have a 10-minute water supply. That might be too short.

We'll go on to the next section, which is 1.3.2. "Persons in direct contact with flame may not benefit from the suppression portion of the sprinkler system, nor will persons suffering ancillary injuries, such as those incurred falling down stairs while in a state of panic in reaction to the fire emergency." If people are in an unsprinklered area, which conceivably could be a hallway, and they knock themselves out, and no one recognizes the fire, it may be a circumstance on which we may not have direct benefit. As we said, it's not a sprinklered area. To that extent, there could be a problem in the unsprinklered area.

Section 1-3.3. The Standard permits ommission of sprinklers in certain areas in which fires are statistically unlikely to originate and in areas of low combustible loading. Fires starting in the former type of area will be uncontrolled except eventually by an outside agency.

A comment has been made that the last sentence is somewhat obvious and could be deleted. The point is well taken.

I am not going to go into Definitions -- I think definitions basically speak for themselves -- other than to say that there are three definitions which we intend to add to the Glossary of Definitions. The wet, dry, and nonfreeze-type system definitions will be added much as they appear in NFPA 13-D.

MR. HAMMERMAN: You should bear in mind that the term "sprinkler head requirements." There's no reason for the word "head."

MR. PRAETZ: You prefer the word "sprinkler?"

MR. HAMMERMAN: Just say "sprinkler requirements."

MR. PRAETZ: I think we can delete the word "head" and just say, "sprinkler."

MR. PIETRZAK: Larry Pietrzak, Mission Research. I notice in the Definitions that there is considerable emphasis on standard sprinkler under the various categories, and I see standard used frequently. I am wondering if we ought to leave the Standard open to other possibilities, such as what Mr. Henderson brought out in his presentation. There are a lot of other types of sprinkler heads out there that may meet these requirements. They are not necessarily tested under the Factory Mutual program. I am concerned that we may be excluding other possibilities that may be adequate in performance terms. We should not restrict other possibilities out by means of design. I think that should be brought out somewhere in the beginning.

MR. PRAETZ: We did not because we only tested one sprinkler. It was a particularly excellent candidate. The intent was to provide the performance standard to get other types of heads approved, which we just didn't have the resources to do.

MR. PIETRZAK: That's correct, but it may lead one to think that if this is really a performance standard, the emphasis should be on performance rather than specific heads. If you have another head that meets the performance, it should be acceptable.

MR. PIETRZAK: That's the very point I made. One shouldn't get the impression that it's only one type of sprinkler head that's been approved. This should be said somewhere very strongly at the beginning, under Scope, for example. I see in your first statement, both mechanical

and performance properties. When I read "mechanical," I got the impression immediately that we were restricting it in some design sense to certain types of things rather than performance. I got the impression just generally as I read the introductory material all the way to the Glossary that we're talking about one type of sprinkler head rather than performance-type approach. That's the point I'm making. That should be brought out more strongly at the beginning, I think.

MR. YAO: Maybe that's only your interpretation.

MR. PIETRZAK: I can interpret operating performance, and I can interpret materials performance. If I were to make an interpretation of what you mean by mechanical, I would think it would be materials performance rather than operating performance. I got the impression that we were talking here mostly about standard-type sprinkler heads like the ones that you tested at Factory Mutual.

MR. YAO: Standards for sprinklers don't exclude kinds of design. The term standard sprinkler can be interpreted as performance oriented. How many people consider pamphlet 13 as excluding any other types of design? Maybe someone representing the manufacturing field can answer.

MR. DOSEDLO: Lee Dosedlo, Underwriters Laboratories. In the Glossary I would recommend that the definition of sidewall sprinkler be added. A sidewall sprinkler in many cases would be a much lower cost sprinkler than a hand or ceiling head, because the amount of tightening could be reduced substantially where you just take a nipple off the pipe coming up through a wall rather than running additional piping over a ceiling, as well as costing unneeded attic space. So I would recommend that sidewall sprinkler definitions be added so we're not leaving them out of the picture.

MR. PRAETZ: The problem with the sidewall head is that we haven't tested it. We have no real knowledge as to how effective it would be in the environment that we have designed to test it. One of the problems is the circulation of air in the corners resulting in possible delay in operation of that type of the head, because the fusible link --

MR. DOSEDLO: That could be determined by the test. Leave the test criteria the way they are. If the sidewall can't meet them, then you wouldn't have a problem. But why not define it?

MR. YAO: Let me try to answer it this way. The purpose of the present exercise it to write a document that will become a performance standard on the basis of what we've learned so far on the contract with NFPCA. There are many, many possibilities in the future that will come in. I don't think this is the moment to add everything into it.

MR. DOSEDLO: I'm just asking why leave the definition out?

MR. CLARKE: I think the answer to your question is that it doesn't belong there. The definition doesn't belong in the spec right now.

MR. DOSEDLO: You're saying that the sidewall can't be a low-cost residential sprinkler?

MR. CLARKE: I'm not saying that at all.

MR. PRAETZ: We could clarify it to the extent that we don't reference it anywhere in the report. To put a definition in of something that we don't reference at this point in time does not seem to be justified.

MR. JENSEN: Rolf Jensen. Following up on that logic, how do you justify the inclusion, then, of definitions of upright sprinklers, dry-type sprinklers, recessed sprinklers, plated sprinklers, since none of those were included in the report?

MR. PRAETZ: I believe that upright sprinkler is referred to. Perhaps some of the others aren't.

MR. JENSEN: The point is, you didn't test them. Neither did you test sidewall. But you have exclusively picked sidewall and left it out.

MR. PRAETZ: The point is well taken.

MR. JENSEN: All right, now that can go one way or the other, gentlemen.

MR. YAO: We assumed the upright sprinkler is intended to be installed on the same location, not on the corner of the wall.

MR. JENSEN: Upright will produce a different discharge pattern, and you know it, Cheng. You don't know you are going to get the same results out of the upright. You don't know you are going to get the same results out of recessed or anything else. So you picked on sidewall for something that just doesn't track with the rest of your logic.

MR. YAO: I don't think we picked on it. We're just saying that there is a great difference in performance between a sprinkler mounted only on the sidewalls and a ceiling-mounted sprinkler in the center of a room which was being tested so far in FM. We cannot say we exclude the sidewall sprinkler. We say we don't know anything about it at this moment.

MR. PRAETZ: The problem is the type of tests we have run.

MR. JENSEN: I accept that, but I say, if that is your logic, you've got lots of other things you'd better drop out of this thing, because you don't have test data for them, either.

MR. PRAETZ: I agree.

MR. JENSEN: You don't have test data for recess; you don't have test data for dry type; you don't have test data for upright, none of it.

MR. CLARKE: I don't think the distinction between upright and pendent or chrome painted and plain or flush and not flush is the same as the distinction between the sidewall and, I'll call it a standard sprinkler. If you as a manufacturer present to the listing agency a sprinkler which is not a

sidewall -- let's say a flush -- then it would fit right into the standard test procedure that is described in this performance spec, and your candidate sprinkler would be tested just as any other sprinkler would be. If it did the job, if it kept the environment tenable, then your sprinkler would pass.

MR. JENSEN: Let me tell you what's bugging me. You're suggesting here a standard that is pushing the boundary, if you will, the lower end of the water application rate. The data that came out of Kung's report show that you were looking for a limiting low-end condition. The same thing comes out of Battelle. Now, at that limiting condition, what may be in a greater density condition unimportant suddenly becomes damned important. You change the way those drops are being thrown around; you change that little difference in air pattern near the ceiling between a pendent and an upright, and I don't know but what you may not find the same answer. That's why I don't see how you can say on the one hand that you can include all these other varieties of distributing water sprinklers saying "We'll test them on a performance basis," but on the other hand exclude something else that could be tested on the same performance basis. It's illogical to my mind.

MR. YAO: I'm sorry, I can't see your point, because at this moment we are talking about the distribution and the discharge pattern, overall performance of a low-cost residential sprinkler and to decide how to accept it. I don't care whether the pipe is chromeplated or copper or whatever, as long as your sprinkler passes the performance test. When you pass a test with an upright sprinkler it doesn't mean a pendant sprinkler would pass, too.

MR. JENSEN: Cheng, if you were titling this document, "Performance Criteria for an Automatic Sprinkler Intended to be Used in a Low-Cost Sprinkler System," I could buy your argument, but you're not. You're trying to

combine performance criteria with the sprinkler and the installation standard in one. The minute you do that you place yourself in all these other problems.

MR. CLARKE: Rolf, will you let us off the hook if we include the definition of the sidewall sprinkler?

MR. BARNETT: Charlie Barnett. In a couple of comments ago, the word "standard," appeared in the phrase "standard sprinkler." "Standard sprinkler" is taken by many to mean a half-inch orifice sprinkler.

MR. PRAETZ: Where did you say the term appeared?

MR. BARNETT: Upright and pendent.

MR. PRAETZ: Oh, we'll take "standard" out. I think your point is very well made. Thank you.

DR. CLARKE: Fred Clarke, Center for Fire Research. I have to keep coming back to this point, but I think Mr. Jensen has his finger on it. The way the project was developed, as I understood it, was to look at what the requirements ought to be for residential sprinkler systems that would improve life safety without also knowing at the same time whether or not there was hardware technology available to meet specifications to do the job. I don't see why it's so terribly difficult to separate the two. I don't see why you can't write performance specifications required to do the job. Then either in a parallel document or in a second part of this document providing the necessary demonstration that this is (a) realistic and (b) low cost. Here happens to be candidate system which meets all this, to demonstrate the feasibility. I realize there is precedent to combine performance with specification, but it seems to me here is a good opportunity to eliminate that sort of confusion. I think any time you begin to blur the distinction between the performance standard and the specification or description, you've got the potential problem that's

been raised here. I for one would advocate right from the outset separating very strictly the performance requirements, the test method, installation guidelines -- separate those very carefully and completely from those systems that do meet those specifications. I would say that's a major observation which permeates the whole standard.

MR. PRAETZ: I think you're suggesting that performance and specifications be totally separated.

DR. FRED CLARKE: Someone picking it up who didn't know the background of the sprinkler, the evolution of the standards in this area, would find it easier to follow and understand. If you made that distinction you would not have to know the history of the sprinkler, because that certainly seems to be the general thrust of the safety standards, in general. It would probably be a good time to do it.

MR. PRAETZ: The point's well made. We considered that that was not the way the program was given to us, to design that.

DR. FRED CLARKE: You clearly can't do one without the other. In the real world, you need to know what it is it can do, so you don't write something unrealistic on the side of requirements. The fact is that now we're talking about putting into place a set of performance requirements which people who may know nothing of Factory Mutual's work will be looking at and trying to meet. And there you are! The first piece of the document is going to need to stand on its own. How it arrives there is going to be relatively academic.

MR. PRAETZ: I think, later on, when we get into the type of tests that we'll run and the specifications for each test, we might deal with what you're talking about. I think your suggestion of separating the two will be kept in mind.

MR. JENSEN: I'd just like to add one or two points to this thought about breaking the document into separate portions. Essentially, it's separating

installation requirements from requirements that have to do with the actual product. I think the climate of the industry, if I can use that term, has typically been one that dictates that there's a certain group of people with certain types of talents who commonly concern themselves with evaluating the characteristics of the product. Certain of the people are very familiar with that. There's another group of people who concern themselves with evaluating the characteristics of an installed system. Factory Mutual wears both those hats, but most people rarely wear both those hats. So I think that's another reason why this document should be a stepping stone in the evolution of better requirements. If it's split, you get one spec going to the people who would be worried about product standards and the other going to people primarily who would be worried about the installation standards, yet both being available for cross reference purposes.

MR. PRAETZ: I think your point is well made, and it will be considered. We'll see if the boys can try the separation and see if it can be achieved. We'd be happy to see whether we can do it without hurting the document.

MR. JENSEN: One simple thing you might give some thought to is changing the word "standards" to "criteria." The word "standard" carries a peculiar connotation to most people in this country, having some force of regulation to it, whereas I don't know that we're ready yet to put the force of regulation behind this document. We certainly are trying to describe here those things which we feel are important to get the job done, and I think that's a major contribution of this document.

MR. PRAETZ: Performance criteria just doesn't ring true to me.

MR. JENSEN: Something other than "standards."

MR. PRAETZ: Because you feel that "standard" is too strong?

MR. JENSEN: It's got a peculiar connotation.

MR. PRAETZ: I think that we have covered the definitions. Comments that I said we would consider, we will consider. I'd like to move to page 9. What I'm basically skipping are the specifications with respect to the sprinkler. Hopefully, if we can move quickly enough through the newer part, which is this fire test performance requirements and the area thereafter, we will be able to return then and cover the areas from page 3 on dealing with the sprinkler head. Because we're running short on time, we're very largely interested in those comments that you have of importance with respect to performance requirements and the specifications that are being established for installation.

On page 127 we have a floor plan of the room that would be used for testing this type of a sprinkler head, providing a fire exposure similar to that which might be present in a residence. The room has measuring devices so that we can check the relationship between the behavior of one type of sprinkler under a set of circumstances. There are a couple of comments on that sketch which I might make. The dummy sprinkler which you have on all of your copies is not necessary; it should be deleted, both in the outline below where it is described, and also above in the sketch where it is located next to the sprinkler. It is not necessary to use a dummy sprinkler.

The dimensions that are indicated in the drawing are those that we used in the tests. Different spacings may be approved for different types of sprinklers under different types of pressures, or with different K factors. If spacings were changed, the spacing of the two sprinklers would be adjusted, and there will be some description in a later version as to how that would be done. Basically, the location of the sprinkler nearest the

couch would be centered in an area based upon the spacing that was being applied.

For example, if the spacing that was going to be evaluated were 200 square feet, a sprinkler would be centered on a 200 square feet area at the end of the room with the couch. A second sprinkler would be located in accordance with the description of the 12-foot spacing. If, in fact, that head wound up being within three feet of the far wall, it would be in that pocket close to the wall on which we have erratic data. If the sprinkler spacing results in a location within three feet of the wall furthest away from the couch, then that sprinkler should then be located in the corner furthest away from the couch, or over toward that closed-off room. It would then be determined by test as to whether or not that sprinkler operated. In which case if two sprinklers operated, the test would be a failure. A successful test is based on the operation of only one sprinkler. Are there any questions on the sketch?

Let's turn to the couch. There is an outline on the section view which is to the left of that page indicating basically the sequence in which the couch is constructed. Below the figure there are the specifications as to how the couch is constructed. It should be relatively simple for almost anyone to recreate the test couch, or the test configuration. There is one thing that is omitted; the base is said to be a 9½ inch high metal frame. There will be a 5-inch space except at the corners of the top perimeter of that metal frame to allow access beneath the material on the couch.

MR. DOSEDLO: Lee Dosedlo, Underwriters Laboratories. We have found that the recreation or reproduction of this type of test using a urethane foam slab can be a very inconsistent field source. Various manufacturers of urethane foam cushions manufacture it in different manners, using different

chemicals, and depending on which manufacturer's urethane foam cushion or couch you buy, you can get widely different temperatures, smoke, CO, etc. And not only that, even with the same producer of urethane foam cushions, the chemical makeup many times changes with time. The brand new urethane cushion burns in one manner and puts out certain chemicals; that same cushion at 1-year-old or 5-year-old burns a lot differently and puts out a lot of different chemicals. So it might be difficult to have consistent and reproducible fire test data from one time to another or from one manufacturer's to another, using a urethane foam cushion.

MR. PRAETZ: The point is well made. At this point there are some laboratory tests being done on the urethane foam that was used. We will add to the specifications the heat of combustion of the urethane foam that was used based upon the Emerson bond calorimetry test.

MR. PATTON: First of all, I was very pleased to see that you substantiate that the sprinkler system can control toxicity. Most people do not substantiate that, and your test data brings that out very well. Secondly, this is not necessary for today but looking into the future, I think we should bring the smoke detector into the total system. When we design a sprinkler system for dwellings we should have a smoke detector on the second floor and on the first floor and incorporate that into the basic consideration of testing, so that if we have a smoldering fire, we actually get an alarm before the sprinkler goes off. I think such a system would be an ideal thing to build into your standard.

MR. BENJAMIN: Mr. Benjamin, NBS. I'm sorry, I don't understand the sketch. The room apparently shows an opening at the front lower right-hand corner. Is that supposed to be a full-height opening? What are the dimensions of that opening? Or are those designs supposed to be something else?

MR. PRAETZ: That is a full-height opening.

MR. BENJAMIN: Of what dimensions?

MR. PRAETZ: The inner dimension on the left is 4½ feet. That's the height looking from the bottom.

MR. JENSEN: The same question relative to doors: are you going to put dimensions on the doors?

MR. PRAETZ: The doors are all closed. The dimensions are not so important since they are closed. They were just put there to indicate that there were doors.

MR. HAMMERMAN: The earlier draft I received shows a 40 inch opening -- or is that a 90 inch opening? It must be 40.

MR. PRAETZ: The 40 inch opening has been eliminated.

MR. HAMMERMAN: Then this supersedes.

MR. PRAETZ: That's correct.

MR. O'NEILL: O'Neill with NBS. This morning, a presentation indicated the number of fatal fires started in the bedroom, as well as the living room. I'm wondering whether the bed found in a residence today might present a more severe exposure from a wider geometric width and present a more difficult situation for the sprinkler to handle this type of fire test.

MR. PRAETZ: The point is well made. There's also a greater likelihood that the bed might be located under the sprinkler.

MR. O'NEILL: For this type of head and this type of design?

MR. PRAETZ: Yes. We felt that there was a greater challenge locating the couch away from the sprinkler.

MR. O'NEILL: But wouldn't that be dependent on the geometrical distribution pattern of a particular head that's being tested?

DR. KUNG: Yes. The performance of the sprinkler depends on the water distribution.

MR. GRAHAM CLARKE: There are distribution requirements incorporated in this spec. The numbers aren't there yet, but there is a category for that, the idea being to insure that the distribution is uniform in some limits, and that one particular radius isn't favored by way of distribution and so forth. So given that the sprinkler discharge is relatively uniform, putting the fuel further away from the sprinkler more severely challenges the sprinkler.

MR. O'NEILL: That's still saying it goes back to the design. I don't want to carry this much further, but it still goes back to the design of the head. Because two heads in the living room may provide much better spray distribution on all those furnishings than one head in the bedroom.

MR. PRAETZ: We're not contemplating the operation of more than one head.

MR. CUSTER: Custer, National Bureau of Standards. On the urethane, you said you specified the calorific value. Are you also specifying the heat-release rate?

MR. PRAETZ: I think if we specify the heat of combustion, the number of BTUs per pound, we should get a close enough profile of the material, so that it should be fairly easily recreated. We're giving the density. If in fact there were retardants added, I think there would be an indication in the heat of combustion of the material which would show that. I agree with you, it would be desirable also to have some sort of a horizontal burn test to supplement that.

MR. CUSTER: Not a horizontal burn test, but weight loss per unit of time, or a rate of heat release type of calorimeter, just for the establishment of a baseline to make sure you've got the same type of material each time you go ahead.

MR. YAO: We think we have to specify further what we are burning. At this moment, I wouldn't want to say exactly what it is. We'll pin it down.

MR. CUSTER: It could be a gas burn.

MR. YAO: It has not been decided yet. We promise to pin it down further.

MR. VOGEL: Vogel, NBS. You've established a first-test performance, a full fire test. You've indicated the room dimensions, the fuel loading, the humidity, relative humidity, the room temperature, your end-point criteria for your tests, so much carbon monoxide generation, so much temperature generation, and which sprinklers would operate. Now, with these performance criteria established, would it not be up to the manufacturer of a sprinkler head to establish where he wants to locate his head to meet these requirements? What I'm trying to say is this: that if you take out the dimensions on locations of the sprinkler heads and let the person who wants to test this system see if this system meets these test performance requirements, then you don't need -- you obviate Rolf's objection to the sidewall sprinkler and head and everything else.

MR. PRAETZ: The problem might be only to the extent that there might not be a valid comparison. I know that everyone would want to test it the fairest way possible. But it's impossible that one organization might locate the sprinkler closer to the fire origin so that the sprinkler would operate faster and be closer to the seat of the fire and enhance its delivery capacity.

MR. VOGEL: The only performance test that I can think of is E-1-19, establishing test criteria. It doesn't tell the manufacturer how he is to build his product. I don't think this is really a fair performance test in that respect; it's not true performance.

MR. PRAETZ: The point is well taken.

MR. DOSEDLO: Lee Dosedlo, Underwriters Laboratories. Have you considered an ignition source at a geometric location on this foam couch on a shielded side of it where water can't impinge directly on the fire; on the back side; or on the side of the couch, heat burning even when the sprinkler does operate?

MR. PRAETZ: It was not done during this test; it may possibly be done in some future program.

MR. EARLY: Early of Monsanto. I think, if you're going to use something as complicated as a sofa, from a material point of view, as some kind of an integral reference point of this test sequence, you're going to have to -- somebody's going to have to provide that standard reference sofa. You're not going to get repeatability by putting a specification on the form and the fabric. I think maybe you've mentioned this. If you haven't, I think you'll find it to be the case, depending on how rapidly the sofa catches on fire or ignites burns.

DR. HESKESTAD: In any fire test, you have to select some sort of fuel that you think will burn reproducibly from one test to the next. You'd like to use something rather easily obtained. No matter what kind of fuel you can think of, you're always going to have problems reproducing the characteristics of that fuel this year as opposed to ten years from now. I think most of us have realized this is a big problem. Even if you chose Eastern White Pine as a fuel, you don't have the same fuel source from test to test necessarily. It is indeed a big problem what kind of a fire source you should select. I don't know if anyone has a better idea than what is recommended here for a fuel source. We are looking for something more reproducible without a tremendous amount of material characterization. We'd like to hear about it.

MR. DOSEDLO: I would recommend a cellulosic material that is more reproducible, namely, a given specie of wood, which for test after test you can put it on a scale and burn it. You will get almost the same weight loss, the same heat release, and other burning characteristics than from a manufactured product. That manufacturer can go out of business, discontinue that model, or change his chemicals without anybody knowing about it.

DR. HESKESTAD: A natural cellulosic is not easy to reproduce. That's a problem. And although with a flaming wood fire, you can control it very carefully, just from the geometry of it -- not so much due to the specifics of its ingredients -- in a smoldering type of a fire it's very difficult to do that.

MR. PRAETZ: I think Dr. Heskestad has pretty well summarized that. I think we may be going into what people in computer terminology call a "no hunt loop." I think it may be best at this point to move on and really, sincerely, ask for any suggestions you would have for a better standard material, or a better way to specify material.

MR. JENSEN: I'd like to go off on another subject. In the area on your diagram, what constitutes the 440 square feet? Is that just what is crosshatched, or is that everything?

MR. PRAETZ: That is just what is crosshatched. And what we're saying, if you'll notice on the side, it should be greater than 6 feet.

MR. JENSEN: So that could be 440 or greater?

MR. PRAETZ: No, we're trying to get as close to 440 as we can. We're trying to maintain consistency of that condition.

MR. JENSEN: I think I can follow that through. My arithmetic wasn't coming out. Okay, now let's take the next step. Look at that diagram, and then look at paragraph 3-9.1, 3-12.1 and 3-12.4, and explain, if you

can to me, or to everybody, how we get to the requirement for 150 square foot space, and how we're going to test sprinklers which are going to be recognized under 3-9.1 and 2-12.4 for larger spaces?

MR. GRAHAM CLARKE: 150 square feet is the area occupied by each sprinkler in that simulated living area.

MR. JENSEN: Is that the area that is not crosshatched?

MR. CLARKE: That's right.

MR. JENSEN: Okay, that's 300 divided by 2 sprinklers, equaling 150.

MR. CLARKE: The answer to the second part of your question: if a manufacturer, for example, comes in with a candidate sprinkler, and claims it will do the job at 200 square feet, that sprinkler would be located in the center -- the left hand sprinkler would be located in the center of a 200 square foot area.

MR. JENSEN: Is that going to require that your 24 foot dimension might necessarily have to grow?

MR. CLARK: Well, no, we're only anticipating the operation of one sprinkler. The other sprinkler is only there to see whether or not it operates. If it does, then the sprinkler itself fails the test, because it hasn't inhibited the second one from operating. There's obviously a limit at which the 24-foot dimension won't accommodate the candidate sprinkler and the tell-tale one. The tell-tale one, remember, only needs the left side of its pattern. It can be right up to that right hand wall, because it's only there to indicate whether it would have operated.

MR. JENSEN: You're changing the configuration factors in the test environment. I think you'd better do some thinking about that. For example, right now 13-D permits you to go to 256 square feet per sprinkler. And there were sprinklers that attempted even greater areas of coverage; if one gets to a 16-foot square, which is 256 square feet, it would mean that the sprinkler, the second sprinkler over, is getting reasonably close to that corner, and

I suspect that you may want to watch that a little bit to see whether you might be getting a corner effect in there that could impede on that second criteria of your test. Just a cautionary note. You may have to put a modifier in there to cover it.

MR. PRAETZ: I think we addressed that awhile ago when we said that within 3 feet of the corner we would move it up to the corner area.

MR. JENSEN: I'm not sure that's the right answer, that bothers me.

MR. PRAETZ: The problem is, what is that corner effect? We're not sure yet exactly where it is.

MR. JENSEN: I realize we can't solve the problem here, but I think it needs some additional thought.

MR. CUSTER: Custer, NBS. I'm still a little unclear as to the purpose of the second sprinkler. In a situation where a manufacturer wishes to verify that a 300 square foot coverage could be obtained in this test method, your room is only 300 square feet; where are you going to put the second sprinkler, and what coverage would it be?

MR. PRAETZ: In this particular room, a manufacturer, logically, who had a sprinkler that could do the job with 300 square feet possibly might have that sprinkler accepted for room areas of less than that. The use of the second sprinkler is to evaluate room size which would require more than one sprinkler to determine if the second sprinkler operated, in which case the test would fail. The remaining specifications are self-explanatory. We will take into consideration the points that have been brought up, particularly giving something besides heat of combustion as a measurement.

The materials, I think, are self-explanatory. Basically, room construction is describing what was run in the test. Ventilation: there would be no ventilation in these tests. Ignition procedure describes basically what Kung

has earlier described to you, the coil with which we replaced the cigarette, and basically, it's very similar to a cigarette ignition. The coil itself and the way that it was placed in the test is described. The relative humidity is given in the range of 40-80 percent; that's just a broad range. We're doing more work trying to further define that, and those ranges may be changed.

DR. HESKESTAD: Ray, this is a point where we stopped back home. Is anyone aware of work that might contribute to defining what range of relative humidities we ought to have? You have 40-80 percent; what do we know about relative humidity for the type of fire we're talking about? We have bits and pieces of information on various idealized burning processes. Any kind of information we could get on that would be very useful.

MR. PRAETZ: Please include it in your letters if you do.

For room temperature, we used a range, 50-90 degrees, which should cover most any condition in a house. Again, we're still evaluating the effects of room temperature, ambient temperature, in the room.

MR. DOSEDLO: I would suggest that we get a little narrower range, because with a range that wide, you would start with one manufacturer's sprinkler at 90° F for the test with a given heat source, with a given amount of fuel burning, then you would only have to raise the temperature X number of degrees for the sprinkler to go off. While if you tested some other manufacturer's sprinkler starting at 50 degrees Fahrenheit, you'd have to burn a lot more to raise the temperature to go off. So I suggest maybe plus or minus maybe 5 or 10 degrees from that 40 degree range.

MR. CUSTER: Custer, NBS. I don't see anywhere in here where you specify conditioning of the fuels in advance. Temperature, humidity conditioning. A lot of the work that we've been doing shows significant delays in fire development with relatively small changes in both ambient humidity and the

humidity of the materials that were being burned. So it probably doesn't matter precisely which one you choose, although the point is that you should have one, and the range of that should be plus or minus -- as Mr. Dosedlo pointed out. You should pick a single value on a range of adjustment, both for fuels and the testing conditions.

MR. PRAETZ: At this point, we haven't done quite as much as we would have liked in this area. What we did was give a range, and hoped we could narrow it down at some point within that range. I agree with your comment. The only thing I might point out also is that most of the materials that we're dealing with here are not highly moisture-absorbent. So the effect of moisture maybe isn't as pronounced as it might be with a more fibrous type of material.

DR. FRED CLARKE: I think Howard Emmons, who did some scale burns at your facility on a urethane mattress found the humidity was very, very important; in fact, influenced the buildup to where it hit the flashpoint by a factor of about two.

MR. PRAETZ: Was it packaged in the cellular material?

DR. FRED CLARKE: Not to my knowledge; it was ticking. You probably know more about this test than I.

DR. HESKESTAD: I would suspect that the test you refer to was influenced by humidity. I don't know that it was, but I would suspect.

DR. FRED CLARKE: It's the only one. It accounted for a variable.

DR. HESKESTAD: Also, the furnishings were not identical in the two tests. One was an old set, and one was, I think, a brand new set of furnishings. So we don't really know for sure.

MR. YAO: I think Howard Emmmons was telling about the influence of humidity on flashover fires. In Dr. Kung's work, the burning behaviors reproduced quite well. We'd like to pin it down further.

DR. CLARKE: How soon did the sprinkler operate after flaming?

MR. PRAETZ: It was 19 seconds between flaming and sprinkler activation.

MR. PATTON: I'm going to raise a question as to whether or not monitoring of the carbon monoxide or the gases is really essential to the testing of these materials. Let me put it in this context. We found out here that we can take and distribute about a .04 gallon per minute per square foot over this area, and the density will control the fire within reasonable limits of control time. I'm wondering if we could back off, and say that now we know the spray power and the water distribution that did this, and go back and test the sprinkler for an ability to put this degree of water over the test area and delay the actual monitoring of the carbon monoxide, so that we make sure that as we're going down the road with these systems, we are in the right ballpark. If you put the testing of the sprinkler itself on a density basis, and the water spray on power basis, that could greatly simplify the testing. I thought this suggestion out as a possibility.

MR. MEYER: William Meyer, Central Sprinkler Corporation. We had the same question that Dick answered. The only thing that we feel is, you talk about droplet size. You might not pick up on distribution. We don't see reproducing each test, you know, in burning the couch. But we don't see why you can't correlate those things.

MR. YAO: I think we're still in the early stage of the program. Nobody can ascertain now exactly how to relate these physical properties with performance. But as time goes by, we can pin down those numbers. I think it's going to be simplified.

MR. MEYER: As we go on with the testing, and we pass your density, and we pass everyone of your other tests, then we come in and you say that you haven't found any of the gases. Things have to be resolved. It could be the humidity factor, it could be many things. And I can see a gyration of tests,

because you can't do everything right and then be wrong at a fire test. It's never happened before. If your distribution is right, if your pattern is right, your density is right; you pass the fire test. If it's borderline, you flunk it.

MR. YAO: Our aim is saving lives. The tenable criteria is expressed in terms of temperature and CO at this moment. Until we know more we'd rather be using temperature and CO concentration as the approved criteria for life safety.

MR. MEYER: You're saying once the sprinkler goes off -- and it takes abou 120 gallons, because you want a sprinkler that does 6 gallons a minute, why don't you put a single jacket pumper connection into whatever supply you have, because in 20 minutes the fire department can get there. And you're guessing that one head will operate. If the fire is right in the center of the two heads, you could have two heads and only have half the water. You might be saving lives. And that approach is very cheap.

MR. PRAETZ: The problem is that much of the piping we're talking about is very, very small, and we're not too sure we would benefit.

MR. MEYER: If water does any good, more water does better.

MR. O'NEILL: O'NEILL of NBS. I support the point that we've got to, at this stage, continue to monitor gas analysis, because first of all, the tenability and the time factor has got to be controlled. And I protest, from the stage of testing that we have done, and from an institutional point of view, which I will detail tomorrow -- we have seen that carbon monoxide is not necessarily controlled at the time of sprinkler operation. We've seen variable increases in carbon monoxide and we're not sure at this stage what those complete factors are. We will have one increase of carbon monoxide over another level of increase in carbon monoxide. So I think it's got to stay at this stage.

MR. HAMMERMAN: Hammerman, Fire Marshal's Office. Has thought been given to using two yardsticks for measurements, similar to Steiner's approach, rather than any single commodity, so that you have some degree of measurement or comparison to two different kinds of fires, two different kinds of heat sources?

MR. PRAETZ: How about three? It's a point of how many? We tried to come up with what we thought was a reasonable total, something that could be recreated.

MR. HAMMERMAN: I was thinking of a controlled gas flame as one test which could be a very easily reproducible test, in which you could define certain very finite guidelines.

MR. YAO: I think we have a tendency to follow the approval procedure for industrial sprinklers which is designed to put the fire out. We're talking about saving lives in residential fires. We try to address the problem as closely as possible to the residential fire scenario rather than, say, to burn a crib and to put the fire out.

MR. PRAETZ: At this point, we're measuring the only things we really feel we have a handle on. Perhaps somewhere down the road it can be simplified.

MR. MEYER: Could I ask another question? When this thing is resolved -- when these standards come out, are we saying, the Federal Government says, that if you follow these standards, and the hardware meets all these tests, that we're going to eliminate deaths in the home? Or is the research lab saying it? Or is Central Sprinkler saying it? Who is saying it?

MR. PRAETZ: What Factory Mutual is doing is responding to a request from the government.

MR. MEYER: From the Federal Government. When these standards come out, they're going to be for the Federal Government, aren't they?

MR. PRAETZ: I think I'd best let Mr. Shaw respond to that question.

MR. MEYER: I don't think we can avoid the liability altogether.

MR. SHAW: Let me represent the Federal Government. The purpose of this meeting was to have FM's performance standards reviewed, modified and forwarded to NFPA. NFPA now has standards which they consider outmoded. NFPA didn't have adequate data when the present standards were written. NFPA did the best it could at the time. We now have more data. We hope the data incorporated in this document will make it possible for NFPA to develop a new and improved 13-D Standard. The responsibility for the new Standard will still belong to NFPA not the Federal Government.

MR. JENSEN: Just one very quick point; this may have been covered. You've got a number of proprietary names with descriptions. I wonder if all of them are absolutely necessary?

MR. PRAETZ: There is a problem, as you point out, with the trade names. And I appreciate your comment. I think it would be well to find some other way to specify them.

MR. EARLY: I think the real, fundamental issue has to do with tenability criteria, the toxicity measurement of toxic gases. I don't disagree at all with the gentleman who asked for heat information, or whether or not a sprinkler system -- the sprinkler system you're proposing -- would indeed limit the toxic gas levels. I think it's premature to set a standard. It's apt to cause so much discussion, confusion and problems that will inhibit the acceptance of the system. You have demonstrated -- and I submit, gentlemen -- a heat-sensitive system. I don't care how much CO is in the room. It turns out that the temperatures in the room can make it go off. Going off, it will deliver water in a certain pattern at a certain rate, and

will control the rate of the burning of that fire. The gases in there are a function of so many variables unrelated to that room, such as the composition of the material, the way it's ignited. But I don't think you've demonstrated a system that controls toxic gases. You have demonstrated a system that controls burning. It ought to be limited to that, and we ought to research further into the question of what happens to the toxic gases under different situations, not just the sofa.

MR. PRAETZ: In a general way, I tend to agree. In another way, the comment was that 75 percent of the fatal fires are caused by CO. We have taken on what we think is the major problem; however, you point out that there are other toxic gases.

MR. EARLY: I didn't say that. That's true, but that isn't what I said.

MR. PRAETZ: There are other gases that could be released, like isocyranate, HCL, HFL, etc.

MR. EARLY: I think it will be demonstrated that when you systematically control burning under different scenarios adequately, you will control the toxic gas situation. I submit you have not yet done the research to demonstrate that, and as you go through the approval process, it's going to keep coming up and coming up.

MR. YAO: Let me try to answer it this way: we have to maintain a tenable environment in the room of fire origin over the entire period, from the ignition to 20 minutes after the sprinkler operation. Over this period, we know we have to control the fire spread. There are two indirect ways of measuring when the fire spread is being controlled: temperature and CO concentration. We had not only to control the fire with the sprinkler, we have to make some that the person is still alive when the sprinkler is operated and throughout the entire period as defined earlier.

MR. EARLY: But if it's a smoldering fire -- not all fires are smoldering

fires - if you have a flaming fire, you probably will not detect CO at all.

MR. YAO: When we started our program, we looked at both flaming and smoldering started fires. Correct me if I'm wrong Dr. Kung; we felt that the smoldering started fire is the tougher one. Before we started the program, most people felt that, in the smoldering started fires long before the sprinkler opened the occupants were killed. That's one of the reasons why we concentrated on the smoldering started fire. We've run some flaming started fires. We did not see the problem as you mentioned.

MR. EARLY: I want to help make this go. I really think you have not demonstrated that it can deter --

MR. PRAETZ: There's a good chance that additional testing -- as Dr. Yao has already mentioned -- will bring it closer. At this point, we've got to get something out. I think that until proven otherwise, we have to make the assumption that we have to be concerned about the effect of the CO too. We may well find out that it's not justified. If we do find that out, I don't believe that we will have lost anything.

MR. EARLY: Cost is an important factor, and some of the other criteria here need to be disucssed. How can this thing be gotten down to the hypothetical $30 and $35 a room? Everything we do adds to the cost. If research demonstrates that sprinklers control burning and don't control toxic gases, don't put a burden on the manufacturers for monitoring toxic gases routinely for a particular system.

MR. PRAETZ: We're doing this to approve the sprinkler.

MR. EARLY: Why?

MR. PRAETZ: To determine whether or not a particular model of sprinkler is suitable for use in this application. It will not be done each time

someone is installing a system as such. In other words, XYZ company has a sprinkler which it feels can be a candidate for a low-cost type of application, it will be tested only once under these present circumstances. The cost is really a one-time thing.

DR. BERL: Just a quick question to Dr. Kung. Did I understand that smoldering fires will or won't set off the water spray? If a fire stays smoldering, will your spray be triggered off?

DR. KUNG: If it is just a smoldering fire, it will not trigger the sprinkler. When the smoldering fire reaches a certain size, it bursts into flame, and the heat from the flame activates the sprinkler. Also, in a smoldering fire, the smoldering process goes through the couch mattress and then somehow spreads underneath the couch so that water cannot hit that spreading fire. As the sprinkler controls the burning rate, it also controls the CO generation.

DR. BERL: Even then, the amount of carbon monoxide given off is quite small, isn't it?

DR. KUNG: The maximum value of CO concentration at eye level was in the range of 1500 to 2500 parts per million.

DR. BERL: So the real damage starts when the smoldering changes into flaming combustion?

DR. KUNG: Yes. Also, from our test results, about 15 minutes before flaming, the CO concentration increased at a higher rate.

MR. HAMMERMAN: Would it be appropriate to address the construction of the room at this time?

MR. PRAETZ: Construction is indicated in part.

MR. HAMMERMAN: I understand what it is, but I'll speak to it. Cut me off if it's inappropriate. It would seem that in typical residential construction that a rated drywall, wallboard, sheetrock or whatever is used, Wouldn't that determine whether the use of PVC pipe is inappropriate?

MR. CLARKE: Dave, I'm not sure that the wall or ceiling material need be listed. Can't you have half hour rating without being listed as such?

MR. HAMMERMAN: Was it not true that the "type X" wallboard has a fibrous content that keeps it together and only that kind is tested for fire extinguishers?

MR. CLARKE: I don't know. I'm sure you know more about it than I do.

MR. YAO: I don't think the rating of the construction material is an issue in the standard fire test method. In the standard fire test, if you let the fire spread and it burns rigorously on the wall, it's already too late. Possibly the temperature and CO concentration in the room already passed the limits.

MR. HAMMERMAN: The point in your scenario is that the temperature would not go to 160^{o} in ten seconds. As such, why not typify the room or residential construction, be it whatever room you choose, using drywall in the ceiling. The walls that don't use any special fire-resistant type, and base the acceptance of these other materials solely on that parameter. Now, a five-eights fire curtain and a dropped ceiling is not typical of residential construction.

MR. PRAETZ: The point is very well taken. We'll need to consider it. These materials were specified because the construction and material was used in previous tests. For that reason, they were specified. They were specified for comparison purposes. We want to start with the same thing. I think the point of considering normal type X in future testing is very appropriate.

MR. JENSEN: On the same point, you might consider the advisability of making that one half hour to 20 minutes. On the question of balance,

typically we know that we can get certain generic floors that will give us a 20-minute rating. Further, you talked about the partition, but you have tacitly ignored the door. Although I could interpret this to include the door, you haven't said so. You're not going to get a half-hour door. Again, what you said earlier would be consistent with the 20 minutes you specified as the gradation for the system. However, let me add that I don't agree with that and I don't want my comments being interpreted as agreeing with that.

MR. YAO: We're talking about sprinklered fire. The proposed safety criteria over the 20 minute period would not expose the walls and doors with the exposure used is the ASTM fire rating tests. If our safety criteria are to maintain the room temperature to less than 160^{o}F, then we must be concerned with 20 or 30 minutes rating on construction material.

MR. BENJAMIN: When Dr. Kung described the tests on carbon monoxide, he indicated that the carbon monoxide was entering from the very beginning of the tests and the criteria were developed on that basis. I'm wondering now why you have changed the base and you're not integrating the carbon monoxide at the beginning, but rather, from the time the sprinkler activitates?

MR. PRAETZ: If you'll examine the drawing at the top of page 11, you will note we are integrating it from the point of ignition. You'll notice that the sprinkler activation is a little ways down the curve.

MR. BENJAMIN: I'm sorry, the sketch isn't clear.

MR. CLARKE: It's misleading. It's from zero.

MR. BENJAMIN: I took A to be between the two vertical lines.

MR. PRAETZ: "A" was meant to mean the entire cross hatched area, and I think perhaps we can indicate it more clearly.

MR. HENDERSON: My overall general comment is if we're going to call this a performance standard, I would personally lean toward eliminating the specification on orifice size completely. Or, if you're going to specify the orifice size, you must also specify that it is based on your experimental work. I don't think this document would necessarily guarantee equal distribution at all. What you observe would occur by somebody else's manufacture. In other words, I'm trying to find out how your head works. So I say, if you're going to specify it, specify it completely or take it out completely and just use it as a performance standard as required in paragraph 2-4.1.2 of the proposed Factory Mutual performance standard. I'll just leave that as a comment. Why specify a head at all? In the copy I reviewed, we had always supplied an oil test and a water test, operating time. It's my recollection Gunnar had done some work on a new kind of test and it was my impression that it was basically superior to the Kung tests.

MR. PRAETZ: I appreciate your comment, but at this point in time I think you're going to another area. Can we hold your comment for a few minutes? We've been discussing carbon monoxide generation; 48,000 parts per million. The instantaneous is 3000, which is peak maximum rate at which the carbon monoxide is being released. The 48,000, of course, is the area under the entire curve.

MR. DOSEDLO: What is the typical basis for that number, 48,000 parts per million? Is there some journal or publication that it's lifted out of? Also, is that at room temperature or is it time at greater temperatures, because I think it can make a difference.

DR. KUNG: This would be at the temperature of the fire involvement. The 48,000 parts per million corresponds at an exposure of 1000 parts per million for 48 minutes. This datum was taken from some published medical journals.

MR. YAO: It is referenced in Dr. Kung's report. You can get a copy of his technical report.

MR. VOGEL: I would suggest that you indicate whether the walls are taped and sealed; also, is it a drop ceiling, a lay-in ceiling or what? You just say a drop ceiling. Is that laid tile or is that furred down and nailed? The point I'm making is this: Could you resolve what types of strips of wallboard you're going to use? Is that on 2" by 4" studs, joints, tapes, sealed properly, a drop ceiling?

MR. CUSTER: I think the point that Mr. Vogel is making is the gas tightness of the ceiling. If there's a plenum up there and there's a drop in the lay-in tile, there's a possibility of loss of combustion where it would be measured. It should be a smooth fit.

MR. TONY SHAW: Tony Shaw. Does the carpet become involved in the burning situation at all? What purpose has the carpet? If it does contribute to the fuel load, I suggest you make a specific requirement that the carpet is shag or loop. The weight of the carpet is important, too. On the matter of drapes, I suggest you do not use the word "Fortrel." Probably "polyester" would suffice.

MR. PRAETZ: The point is well made. We should avoid the trade names. We are interested in whether or not the carpet is ignited. If it is ignited and fire travels to the extremity of the carpet -- the test would be considered a failure.

MR. PIETRZAK: I don't see anything explicit here that says anything about fire containment in terms of the performance criteria. Is this applied at certain levels of CO and temperature? Is that the way your handling it?

DR. KUNG: Yes.

MR. PIETRAZK: Is it conceivable that one could get a spreading fire and yet maintain a certain temperature?

MR. YAO: As long as people are not getting killed, that's the idea.

DR. KUNG: When the temperature is below 160°F, I don't see any likelihood of fire spread.

MR. PIETRZAK: But is it desirable to be more explicit? The question I'm raising concerns the small containing fire. Shouldn't there be a requirement about it in addition to meeting the CO criteria?

MR. PRAETZ: The test, if the flames travel to the extremity of the carpet, would be considered a failure. If the temperature of the fire exceeds 160° for ten seconds where it's being measured, the fire did go out of control for the purpose of the test. Temperature, the criteria we set on page 11, stipulates that during the entire test temperature shall not exceed 160° for more than 10 seconds, and only one sprinkler shall operate during the test.

MR. JENSEN: Can I ask where you determine the basis for that 160°F?

MR. PRAETZ: 160° was selected on a judgement basis. There is some evidence that we can withstand temperature of 212° for up to half an hour. (NOTE: Should have been half a minute.)

MR. JENSEN: Good heavens, no. I would suggest somebody better go back and look at some medical journals.

MR. YAO: Do you have a question on the 160°?

MR. JENSEN: I'm trying to recall some history about this. I can recall about ten years ago having served on a special investigating jury in Chicago involving six deaths in an atmosphere in a tunnel where, ultimately, we found out that the reason these people expired was because of a combination of about 140° with a very high humidity. And when you go through the medical literature in that area, you'll find that the

combination of temperature and humidity and time of exposure is presented on a psychometric or a three-dimensional type of chart, and it describes survival times. I would not presume to claim expertise in this area. I would suggest that the number be checked with some people in the medical fraternity who do have expertise. It may not be as safe as we think it is.

DR. KUNG: 160°F for ten seconds.

MR. JENSEN: I appreciate what you are saying. What I am saying is that 140° for 20 minutes may kill you, and that's per minute under this criterion. In fact, in the deaths I investigated, those people died at 140° temperatures in about 7 minutes.

MR. YAO: 160° in 10 seconds is a temporary flash.

MR. PRAETZ: I think your point is well made.

DR. HESKESTAD: There may be other comments on that question in the audience.

MR. MADDEN: Recent work which we completed in the early part of this year at UCLA by a number of MDs looking at the tenable limits of firefighters may be significant. One of the most significant points there is that the temperature as well as the humidity was substantially raised to where we thought it was a reasonable one, as opposed to being what would appear to be some prohibitive figure of temperature and humidity a few years ago.

MR. DE CICCO: I think that your scenario makes sense based on your approach and the constraints you have to worry about, but I agree with what Professor Jensen said: there are a lot of fires that occur, not with the windows and doors closed, as your scenario assumes. They occur in April and May and June and July, particularly in the low income, ghetto areas of our large cities. When those fires happen, given the furnitures, given the wall coverings, all existing and not new, as you're assuming, then what happens? Those fires run away. We talk about 4-5- and 6-minute fires as being the typical time for a flashover. All you do is move the

people out and drop the match in and you get a very fast fire. In a situation like which I describe those fires start and they grow very fast. Your 160°, which fits your scenario, won't fit. A couple of things may happen. First of all, there's going to be more carbon monoxide generated than you think. I'm worrying about people in some of the adjacent rooms. Some of the people getting killed are not being killed in the fire room. I fully appreciate your problems and constraints. But the final test has to be the real world put there.

DR. KUNG: We have run a few tests with flaming-started ignition on the couch and the sprinkler activated pretty early in the stage. And the data has shown that it could meet your kind of criterion. Also, from our past experience, as far as the toxic gas is concerned, rooms with doors closed and windows closed are more severe than rooms with open windows because in the open windows, the toxic gas tends to go on the top layer and then go out. There is always fresh air coming in.

MR. DE CICCO: We ran 6 rigorous tests in the Bushwick area of Brooklyn. In 3 of the 6, as I remember, we were looking at 400°, 425°, somewhere in the room when the sprinkler heads decided to go off. This suggests to me that you could be in trouble in a real fire because of the temperature and because the fire will carry beyond the room that you're trying to contain it in.

MR. PATTON: I'd like to comment on that. We've had adequate proof that the sprinkler system will control the fast fire. Where the fire is fast, the sprinkler activates, it throws its water into the environment, and we haven't had problems. But a lot of people said if the room is all closed up, you will get a very low smoldering fire. You won't kill the people before the sprinkler opens. I think one of the most important and significant results of the FM research is that it has proved that the

sprinkler system can be a device to protect against the smoldering fire. That's a very significant result. Another thing I'd like to put in perspective is a statement of Rolf Jensen this morning, when he said what we've got to look at is "the bottom line." Rolf has prepared studies of installing the existing NFPA 13-D system in residences. In a 2000 square foot residence, ranch-type with 1000 feet on the first floor and 1000 in the basement. He had prices to install the system from $1500 to around $2500, which is a very high price. Now here is what I did. I took the criteria you people developed - 6 gallons of water per minute for one sprinkler opening. I doubled that and allowed for two sprinklers to open. Then I designed the system for the same building based on your criteria. Using $12 an hour for labor, we were able to install that sprinkler system for $362. You can install a sprinkler system in an existing home for less than $500. What has been demonstrated here is that the sprinkler system can protect against the smoldering fire - in essence all types of fires. Also you've created criteria that would make the marketing of the sprinkler system attractive from a dollar and cents viewpoint. I think that's a very significant result.

MR. HARRY SHAW: Paul, I want to address my comments to the question you raised. To the extent that NFPCA has resources, we will do as complete a field evaluation as possible of anything that we put into a performance specification. I'm talking about going into Bushwick apartments, also going into rural areas with the system. We will not be satisfied with just the laboratory-type tests. I hope that will give us more experience and more confidence in what we're coming out with, or at least, we'll know what it does after it's been tested.

MR. VOGEL: For your CO generation, you set a tolerance level of about 3000 ppm, and a temperature tolerance of 160^{o}F. Have you ever given thought that the two operate together? I don't think a person can take 3000 ppm at

DR. HESKSTAD: Since we don't know much about the combined effect, if you have any suggestions as to what we ought to do, it would be appreciated. Maybe we should be very conservative; maybe not. We're not trying to produce a sprinkler system that would protect against a particular test fire. We're trying to produce a test which will do a rough job of screening out the good from the bad.

MR. YAO: I have always treated this document as a report, written in a standard format. We're not saying this is the standard, with every word on every line fully evaluated by the Committee. We're writing a technical report and in the standard format to tell you what it is in the common terms.

MR. JENSEN: Just two quick comments. To set the record clear, the price range in our report was from a low of $655 to a high of $2580. More important, however, I have been concerned through this whole discussion about whether you really have done enough evaluation of the fire scenario of the residential occupancy to be certain that this test represents a reasonable condition for measurement of the CO and the temperature. What's bothering me is that I can visualize a water discharge which will slow down the combustion even though it doesn't extinguish it. I can see residential conditions where we could get a fast burning fire that is shielded from direct sprinkler water application, enough to set off the device and then control burning at a lesser rate but with a higher generation of CO, and a possible higher generation of heat. I guess what I'm referring to is a suspicion that Kung also recognizes. There's a whole fruitful area for more research. I am putting in a pitch that will help you guys pressure Harry Shaw and Joe Clark to keep the money coming so you can get needed information. Otherwise I can see this thing ending up in my lap in 13-D, having to

worry about how we get this to the public without a sufficient data base.

MR. YAO: I think you're right, we address only one important scenario. It was mentioned earlier by someone about the failure mode. Somewhere along the line some kind of failure mode fire tests have to be conducted. I think for any newly developed system you obviously want to find where it might fail.

MR. JENSEN: My concern is this. We've sold the public in the last two years in putting smoke detectors in residences. I don't know yet whether we were right or wrong in a long-run situation. Should those smoke detectors start failing in two years, three years, five years, or seven years and people start losing their lives think of the backwash of that situation! The public loses believability in us as people who are recommending how they should protect themselves. Now, as I look at the development of suppression systems for residences, I would like to see this group, those who are concerned about putting that fire out and getting the right equipment in, to go down the path in a way that will make doggone sure that that backwash day never comes. I have real concern about that.

DR. HESKESTAD: To many of you, these comments sound very reasonable, and they do to me, too. We are very much concerned about establishing standards on the basis of a limited number of experiments. But really, our data base is vastly larger than what this particular project is. It rests on other experiments done in the past not only by ourselves but other people. The one thing we're really concerned about is the flashed-over fire; the flashed-over fire causes tremendous generation rates of CO, and you've got seconds. I believe many of these fires have been investigated. In a flashed-over fire, you contaminate in seconds.

You don't need much water to prevent flashover. Past experiments have suggested that the kind of water densities involved in this standard are really in the ballpark on what would prevent the fire from flashing over. And that's really a great battle won right there. The room may be continuing to burn, but now it's a small-time game. It's not the big-time game involved after the flashover. So I think we have fair confidence that a system of this kind can do a great deal already. But I must agree it would be nice to have a greater experimental base than we do now. I think that we need money for that.

MR. BOWMAN: Mike Bowman, U.S. Forest Service. I guess it's getting late in the day, but I've got to say something. I'm not a researcher; I'm not after research money. I'm not a manufacturer. But I'll tell you what I am. I'm a guy that's got to go out to these people and tell them something to do to save their lives and save their property. What I have been hearing today is we're going to research, we're going to research, we're going to research. I can appreciate the need for having a data base, because every day I have to make decisions without data, and it's a tough job. But it all comes down to a choice of making a decision with less data against making no decision. Your position is weighing saving somebody's life against waiting to give them something based on better knowledge. I see people out there right now with nothing, and I mean nothing. So what are we now doing? We're buying more fire trucks, we're buying more insurance policies. Have you seen an insurance that's totally going to save life or save property? I haven't, but that's the best bag of tricks I've got in my situation. Smoke detectors? Yeah, they may not last for five years, but if they last for a year, they may save a life and $50. I say let's get on with it. Yeah it's nice to have good standards and I believe in

reliability. But let's give them something. Do you realize that the 4 hours we've spent here debating these issues about the minute level of CO and the whole ballgame that you've been debating, somebody out there is dying. Some firefighters are getting hurt. Now what are we doing? What's our objective here? Is it to get more money to do more research? I really have to ask myself the question. And I'm an amateur. But buddy, that's from an amateur's standpoint. Do we have a conscience? What are we doing here? And I think we're in a pretty serious business. From what I hear, we've got something that may save some lives and it may make firefighting safer or the impact of fire less on this country. I don't think we've got a record in the U.S. - or at least I haven't seen any proof of it - to be proud of. Now, if anybody's got something better that I can take out tomorrow and apply, I'm wide open. But if you're talking about ten more years of research, or even two more years of research to verify what we've verified, I'm sorry, gentlemen. I've got a problem with that. I know from a manufacturer's standpoint, yes, you've got a reputation to maintain and I appreciate that. But what are we going to give the people? And when are we going to give it to them? If we can put a man on the moon, we ought to be able to help put out a fire.

MR. PATTON: I'll only put this one added thought in, that whenever we come down and we've got a practical system that we can really sell to the public, everybody says, "Hey, we can't do it, because we don't have a sufficient data base." But day in and day out, year in and year out, we're grinding out standards by the thousands, and we've been imposing them on the public and sometimes costing them fantastic sums of money

without any data base at all. So why is it that only the systems that can sell need a data base?

MR. MADDEN: I'm a retread, coming out of 22 years of the fire service and representing manufacturers. I've been where that gentleman has been. The particular point I see is that if we had done this type of homework and in this particular detail a few years ago with some of our detectors, maybe we wouldn't have this severe reliability problem we're having right now. But I do agree with a number of points Mr. Bowman made. However, being on this side of the fence, in my second year, I think this is the type of homework we have to do more of so that we can avoid some of the present pitfalls.

MR. YAO: Research and getting data are two different things. We were not talking about research, we were talking about getting the needed facts. I don't mean we have to research forever, but I think if the data are needed, we have to get them. Otherwise, we would force something on the public that we could regret in the future.

DR. KUNG: Let me just point out one thing. The grant we had from NFPCA is called "Development of Low-Cost Fire Protection Systems." It has no "research" in the title.

MR. HARRY SHAW: Thank you, gentlemen of the Panel.

Closing Panel Remarks

Harry Shaw
Director, Technology Development
National Fire Safety and Research Office
National Fire Prevention and Control Administration

We have had a full and rewarding day. The presentations based on solid programs clearly indicated the possibility of and the need for a low-cost residential sprinkler system. It was also evident that the required technology is available to design and produce an acceptable system which could contribute to the reduction of the Nation's fire losses.

The excellent participation by the attendees has provided new inputs and views which will influence both Factory Mutual in its efforts on the proposed performance standards and the NFPA 13-D Sprinkler Committee in its work on a revised 13-D Standard.

While some of us feel that progress is slow, we must recognize that "life safety products" involve extreme liabilities and that in itself demands cautious progress. We must learn from history and avoid mistakes of the past. Clearly the first priority of our program is the need for a standard test which may include one or more fire scenarios and which is truly representative of most of the residential fires. Our second priority is the performance criteria of the system in the test mode. If these two priority items can be accomplished, we will have an excellent opportunity not only to reduce fire losses, but also to avoid some of the problems being encountered by the smoke detector industry.

Thank you for your attention and your participation.

MANUAL FIRE COMBAT

ANTIQUATED, DANGEROUS AND EXPENSIVE

Byron Chaney
Chief, Palm Springs, CA
Fire Department

I suspect that the main reason I have been asked to address this august group is because of three descriptive words that were used in a talk given at the St. Louis Third Annual Fire Protection Conference last month. My statement -- and I'd like to expand on it this evening with you -- was: "I believe manual fire combat, as we know it, is antiquated, dangerous and expensive."

Before I do that, I am aware that it is not popular for one in an occupation such as mine to criticize that occupation and I feel it necessary to let you know "where I'm coming from". You must understand that my background is that of a firefighter: for some five years, a line officer, fire lieutenant and captain for five years, and the remaining 17 years have been in an administrative capacity as assistant chief and chief of department. Further, my background experience has been in three fire departments which ranged from protection of 80,000 population to some 50,000 people in my present city. I make that point because I do not profess to you to have fireground experience in major cities. I am sure some of the kinds of things we are hoping to do in Palm Springs may not be possible in other jurisdictions of very small or very large populations. I do feel however that my description that manual fire combat is, throughout the United States, antiquated, dnagerous and expensive is applicable to any size city.

I'd like to share with you my feelings about what I mean by each of those descriptive words, then suggest to you a "Why can't it be" type of solution and end my remarks with a plea to you.

Why do I feel, after 27 years, that manual fire combat is antiquated, dangerous and expensive? Taking one word at a time, let me explain:

ANTIQUATED

Everyone in this room has seen the picture I'm thinking of. Picture with me, if you will, in the background is a structure in flames, several stories tall, fire is showing from every window, in various positions are hose streams manned by obviously heroic firefighters. The hose streams lead back to an old-time hand pumper, men are lined up pushing on the compression bar providing pressure to the hose streams. You have all seen the picture, and I hope you have it in your mind. Now, what today has changed. Yes, the firefighters are better protected, their turnout clothing is better than in those days, but not really good enough. You are aware of the work still going on to provide better firefighter protection, but it has improved from our picture. Yes, the firefighter now has breathing apparatus so we can send him into this inferno instead of making an exterior attack. Yes, we have modern fire engines now instead of hand pumpers. Yes, we use better nozzles, nozzles that break up the water droplets and utilize the fire killing power of steam, and yes, we have better communication systems to better utilize our firefighters. So, I do not say we haven't made advances but I do say our advances have been in the wrong direction. We've developed better and more efficient methods of doing the same old job of getting water at the seat of the fire manually, but wouldn't a more productive approach have been to work toward containing the fire within its room of origin through a fixed suppression system? Why have we developed bigger and better nozzles to do the job in the same old antiquated way? I believe we've been talking the wrong approach.

DANGEROUS

Why do I feel manual combat is dangerous? In my career, I have been somewhat fortunate. In 27 years, I know of only one fellow firefighter friend of mine killed while fighting a fire. A man I worked with in Menlo Park, California. He left that department and was killed while with the Santa Rosa Fire Department a few years later. You know that firefighters are classified in our most dangerous occupation. You don't need to be reminded of the statistics but here are a few anyway:

The death rate for firefighters is nearly twice that experienced by police officers.

One hundred and ninety-six firefighters lost their lives in on-the-job accidents or from occupational diseases in 1975.

In 1975, there were 90 on-the-job deaths per 100,000 firefighters.

Seven hundred and twenty-one firefighters were forced to leave their departments or retire because of occupational diseases in 1975.

To my knowledge, little has been done to try to cost out these figures but obviously the annual taxpayers' costs for these deaths and injuries are staggering.

Remember the picture just described and the advancements I noted were made in nozzles, apparatus, turnouts and communications? The crazy thing about all this is the firefighter, God bless him, is still following our orders, he's still charging into that burning building with the roof falling in on him, he's dropping from exhaustion, he's getting himself hurt and even killed, and it's crazy, but he's not even complaining. The only complaints I hear is he wants more money and shorter hours. I have never heard of a firefighter being killed at a fire in a sprinklered building.

EXPENSIVE

Why do I feel manual fire combat is expensive? For the fire service personnel present, this is going to be "old hat," but on the chance that some of you are not aware of today's costs for manual fire combat, here's a 3-minute cram course in the "Economics of Fire Protection." It would obviously be a good deal cheaper if we could schedule our fires, but until we can, we generally have to man for our normal anticipated fire in my size city and develop supplemental resources for that small percent of alarms we are unable to handle with on-duty forces. For my purposes, let's take a theoretical bedroom community with, say homes of an average size of 2,000 square feet. Yes, that's a rather large house, perhaps, but it is a rounded figure to work with. Let's set a fire protection goal for our theoretical community that we do not want to allow more than one home to burn. In other words we don't allow a fire to spread from one home to another, and we want to provide sufficient manpower to control a fully involved, single-family dwelling of 2,000 sq. ft. Using Warren Kimball's formula of 2 - 4 GPM, and we'll use 3 GPM, to contain 100 cubic feet of fire area, we find that we need the capability to deliver 480 GPM. Now, that's not a lot of water, but what will it cost this community to man up to deliver that small amount of GPM? Let's say that we want two 1½" lines each delivering 100 GPM on the house fire, to give us a two-point attack. We need one 2½" line delivering 250 GPM to give us 450 GPM. We need a fire engine at a cost of 60 - 90 thousand dollars. We need to man that engine with four firefighters, one to handle each of the two 1½" lines and two to handle the 2½" line. Let's even say we have the automatic nozzle so we don't need the pump engineer but we ought to have an officer supervisor. So, we can get by with five people

on the engine 24 hours a day. If you divide 168 hours in the week by the duty week, and I am using 56 hours because I am from the West Coast, times 10% for leave, plus annual salary and fringe benefits, you are, as in the case of Palm Springs, at 71,000 dollars per around the clock position. We have five on this engine so we have a cost to man an engine that can deliver 450 GPM and handle a 2,000 sq. ft. fire at $355,000 per year. The apparatus will last 20 years, but we will need a fire station to house the unit. We need communication and equipment but these are all one-time costs, so for our purposes we will not even bother with them. We may have two calls at a time so we better have a second fire company and that's another $355,000. We end up with a budget of $710,000 annually and we can deliver with both companies 860 GPM or handle together about a 4,000 sq. ft. structure fire. That's the very reason you don't see very many fire companies manned with 5 people. Most cities my size set a goal to handle a 2,000 sq. ft. fire with either the full first alarm assignment or all on-duty personnel and sure, that's the very reason we have volunteers because of costs like these, and they do an excellent job, but when it costs some $71,000 of taxpayers' money to put one man on duty around the clock, that's expensive, particularly in light of what the one man represents in the way of manual fire combat capability! Keep in mind that these kinds of manual fire combat costs are annual on-going costs. Think about the difference in cost if that 2.000 sq. ft. fire building had a one-time cost fixed suppression system.

What's the answer to our antiquated, dangerous and expensive approach to manual fire combat? Simply put (because I'm not expected to provide the answers, you are) the objective of manual fire combat is to hit a fire before

it gets to flashover. Fire combat, prior to flashover, is not that dangerous. We can make an aggressive, relatively danger-free attack on that type fire. We need to develop a fixed suppression system that is so low cost that it becomes economically feasible to install in every structure that is built in this country, and we need to develop another type system that is economically feasible for retro-fit in existing structures. I am convinced that a "cup" of water, properly applied at the right time can do so much more than we can do manually with thousands of gallons of water at an inopportune time through manually held hose lines. I believe that you can develop a fixed suppression system that can work with only those amounts of water that are necessary for domestic use. I am convinced that our past emphasis has been in the wrong direction and my plea to you is LET'S CHANGE THE DAMN SYSTEM!! I believe that we have the technology to allow the cities of our Nation to manage their fire losses and let me explain what I mean by "Manage our fire losses."

Realistically, we know that we cannot prevent all fires and we know that as a result of fires, we're going to have some fire loss. That's not to say that we couldn't design a fire protection system that wouldn't allow any fire ignition but neither you nor I would want to live in that type of environment. So . . . if we will not accept zero fire ignition, obviously we will accept some ignitions and the resultant losses. With your expertise, we can develop a system which will allow a community to clearly identify their acceptable loss limits. Loss limits which will reduce the need for massive manual fire combat forces, a system that does not penalize a property owner by increasing his taxable value and thereby raise his taxes, loss limits which are acceptable to our communities. How? By taking a closer look at out existing standards and

addressing the question of overkill in our standards, might it not be better to contain 95% of ignitions below flashover with fixed suppression systems that our people can afford than to call for 100% effective systems that are not, or cannot, be installed because of cost?

Without meaning to imply a threat to you, let me share what might well happen if you do not act. I believe I am pretty much an average kind of fire chief. I am faced with a rising fire department budget and need to recommend alternatives to my legislative body. I am moving toward accepting my "gut" feelings that we can, and should, deviate from the national standards you prepare for our guidance. That should be scarey to you because we may well be wrong, and if we are, lives may be lost needlessly. I am hearing that much smaller quantities of water than were thought possible can hold a fire below flashover. But, I say to you, "prove to me we're wrong, find the right path to help us do our job of providing adequate fire and life safety for our people."

I noted in my opening remarks that I intended to review the descriptive words that fire combat was "antiquated, dangerous and expensive." I hope I have done that. I also noted I'd be making a plea to you and I hope you have heard my plea.

My last comment to you is a quote from a prayer I recently heard. It goes like this: "Let us not use this meeting to mark time, rather, let us use this time to make our mark."

Thank you for listening. The NFPCA has set a goal of reducing life loss by 50% over the next generation. YOU are the only people I know of that can make that goal a reality.

Welcome

by

Richard Custer
Chief
Program for Fire Detection and Control Systems

NBS/CFR

For those of you who don't know who I am, I'm Dick Custer, Chief of the Fire Detection and Control Systems Program and currently acting as Assistant to the Director of the Fire Research Center. In that capacity I would like to welcome you to the Center for Fire Research.

The Center for Fire Research is located here at the National Bureau of Standards and was established as a Center when the Act was passed by Congress to establish the National Fire Prevention and Control Administration. We are separate, in a way, from the Fire Administration in our day-to-day operations, but our programs are coordinated where they overlap with the work that's going on in the Fire Administration. We also have our dollars funded through the Fire Administration budget. There's a single Fire submission for the entire Department of Commerce and our budget, which used to be part of the National Bureau of Standards' budget, now is part of NFPCA's.

We provide the Fire Administration with technical assistance in a number of areas and we draw on their experience in the areas of data, national fire estimates, as well as most of their other activities. We have a very close working relationship on the senior management level and also in several areas at the project level. So it is kind of a

family affair. We are all working towards the same goals and, so far, we are managing to do it with a minimum of ruffled feathers and a lot of cooperation. What's happening here this morning represents the kind of cooperation that we've had working with Harry and with some of his contractors on review panels, providing technical input and a sounding board for the work as it's been progressing the last couple of years. The work of the Center for Fire Research is divided into three areas, two of which are in-house, one of which is outside with a very small support group in-house.

I'll talk about the outside activity first. That's the Office of Extramural Research. This office accepts proposals for contracts and grants in fire research and runs the basic fire research program that the National Science Foundation supported for a number of years. In the recent past, there has been a shift of the emphasis in that research from largely very basic combustion and energy work to an attempt to get the centers of academic excellence and the contract research laboratories to work on problems that are more specifically related to the real world, and to the goals and objectives of the Fire Center's Five-Year Plan. That is not to say that we're neglecting the basic research, but we're trying to get some of this high-powered talent to apply some of their knowledge and skill to real-world, engineering type problems. The money is funneled through the Office of Extramural Research.

The Fire Science Division represents our internal basic research capability, and it is divided into four groups.

The Hazard Analysis Group maintains a research library within its Fire Research Information Service. We like to think it represents one of the finest state-of-the-art fire research libraries in this country and perhaps the world. The library has thousands and thousands of documents, all neatly catalogued and available. It also has computer search capability to look at other types of data bases outside of our own.

The Hazard Analysis Group also does studies in decision analysis. This is a fancy statistical modeling approach to try to determine what happens to the end result of a series of events if we change just one variable. The most recent work we've done in this area relates to the upholstered furniture standard. A number of alternative outcomes were generated, based on the upholstered furniture standard alone, the upholstered furniture standard with detectors, and detectors without an upholstered furniture standard -- just to see how these variables might, from a probabilistic standpoint, affect the end result of any given standard being put in place. Though it's not a final answer, the modeling does allow a test of sensitivities of things. We make assumptions such as the upholstered furniture standard would be in place tomorrow morning at 9:00. What would happen to fire losses under those circumstances if it takes 20 years to get all of the upholstered furniture applied, then what will our fire losses look like at the end of that 20 years, assuming that we have a slow buildup of reduction in fire from that intervention strategy ?

The Chemistry Group works in the basic chemistry of combustion trying to determine what exactly is going on in the flame zone, what is going on in the pyrolysis zone close to the surface of the material,

and what types of chemical inhibition mechanisms can be introduced either into the materials themselves to reduce flaming or smoke generation or, after the fact, in the form of fire suppression agents. We're not doing much in the way of chemical agents right now. We're working really with the microstructure of flames and chemistry at that level.

The Toxicology Program is trying to pinpoint what it is about gases that are given off in fires that makes them toxic. In the course of doing this, the program has developed a test method, a protocol for evaluating candidate materials -- it could be wall finishes, carpet, upholstered furniture, any material that might burn -- to screen out what we have been calling supertoxicants, things that are more toxic than what people have been accepting in their environment for years. The base line right now is wood. The protocol for this is not complete. We're going through outside reviews with experts in the fields of toxicology, trying to develop a right kind of test box. It's an animal test, and we'll be looking for lethal effects and effects on behavior of animals as a measure of the toxicity of either single materials or composites of materials burning together.

This project has the potential for regulatory purposes. We are trying to arrive at a means to control toxicity as much in the same way the French have done by controlling chlorine and nitrogen-bearing polymer materials in public assembly buildings.

The Physics and Dynamics Program people are trying to get at how fire grows and spreads from a mathematical standpoint. They are attempting to develop models to predict -- given certain information about the fuel bed, the room geometry, the ventilation parameters -- how big a

fire one would get and what would be the time to flash-over at some critical temperature. By being able to predict these factors, hopefully, we might be able to model some of the things we'd like to test in full scale and determine which combination of materials really warrant full-scale testing. Thus, we would be able to save some money, a major problem for people doing full-scale testing. It's very expensive. So if we can get the modeling under control to predict things, we ought to be able to at least screen out many of the major full-scale tests and only concentrate on the ones that have real significance.

The other major component of the Center is the Fire Safety Engineering Division, whose goal is primarily to transfer the technology developed by our contractors and grantees and the in-house basic science group into some sort of usable engineering product. We in the Engineering Division also do some research of our own. It's somewhat less basic, very much applied.

The Products Program, or Products Section, deals with flammable consumer products exclusive of furniture; however, it has a remnant from past work, the upholstered furniture standard. The Section developed it, and is still working with the Consumer Products Safety Commission to try and get the standard in place. The Products Section has worked on such things as flammability of Easter grass, that green stuff you stick in a basket, put hard-boiled eggs in; Christmas tree lamps; wooden candle holders -- things like that. Most of the Section's support has been from the Consumer Products Safety Commission until recently. The

group is now just beginning to do some work for the Mine Enforcement Safety Administration, working in the area of electrical and other types of fire hazards in mines.

The Furnishings Program is trying to deal specifically with furniture, particularly large items, although they've worked with Parson's tables and smaller things. They are particularly involved with upholstered chairs, beanbag chairs, trying to find out how these items interact with other things in the room-fire situation. Again, this group is leaning toward modeling activities, but most of the tests are full-scale, single-item furniture fires. The program has also done some work on mattresses. I believe John O'Neill will mention some of that mattress work, since it overlaps with the work we've been doing in the detection/suppression project.

The Construction Group has been working on mobile homes, on tests for ease of ignition. This program has also been doing some basements burns for HUD, studying the fire aspects of various types of residential floor-ceiling assemblies, using full-scale tests.

Let me mention the Detection and Control Program very briefly, without treading on John O'Neill's territory. The work deals with fire detectors, primarily smoke detectors right now; fire suppression systems, primarily sprinklers at this time; and smoke control systems. Smoke control systems are those being built in or redesigned systems in existing buildings using the HVAC, heating and ventilation and air conditioning capability, to control the movement of smoke in buildings by creating pressure drops. By means of building design one can bottle up smoke in a certain area, a predetermined area, and keep the environment safe, at least from a smoke standpoint.

The Program for Design Concepts is in the Fire Safety Engineering Division, but the work encompasses everything on both sides of the in-house research, plus the extramural research, plus the things that people who are not funded by CFR or other government agencies are doing. This group is attempting to pull together a total fire safety design procedure for building based on all of the work that everybody's doing. This sounds like a very large and ponderous job and it is. To date, some of the projects have included study of human behavior: what do people do in buildings, and how do the behavior patterns affect the design of the building -- or rather, how can they? If you know enough about behavior patterns, you should be able to design buildings from an egress standpoint to match the behavior patterns of people. Or, conversely, are there things in the way that we're designing buildings for egress that are acting to compound the problem of human behavior?

The group has been doing work mostly for HEW. Included is work to develop an evaluation system for health care facilities that will determine for an existing building a degree of equivalency, that is what the building has or can have by addition of certain fire protection measures to a given base-line standard. The initial work was built around the 1967 edition of the Life Safety Code. The methodology is flexible enough so that it can be recast in terms of any life safety code. The system works around the Life Safety Code now, but the concept could be applied to a building code or any other way of codifying levels of safety in a building. Ultimately, we would like to have come out of the Design Concepts Program a synthesis of everything we know about fire science, fire engineering, into a rationally based design approach for fire-safe buildings. And that's what and where we are at the Center for Fire Research.

BRIEF STATUS REPORT ON

NBS/CFR SPRINKLER PROJECTS

John L. O'Neill
Center for Fire Research
National Bureau of Standards

The National Bureau of Standards/Center for Fire Research (NBS/CFR), Program for Fire Detection and Control Systems is presently engaged in two major sprinkler research projects. The first is a study of automatic sprinklers in health care facilities, and the second is a study of sprinkler and spray methods for the protection of open or partially open stairways. This is a brief report on the status as of November 1977. Full technical information will be presented in final reports when projects are completed.

I. Health Care Facility Sprinkler Project

This project is one part of an overall fire safety research program being conducted by NBS for the Department of Health, Education and Welfare, Public Health Service. The purpose is to determine engineering design parameters for automatic sprinklers in health care facilities. In determining these parameters, the effectiveness of sprinklers is being measured in terms of:

- o Overall fire control.
- o Time available for evacuation.
- o Maintaining tenability conditions for patients who cannot be evacuated.

Details of the test facility and instrumentation for performing this evaluation, are shown in figures 1 thru 5. The current test program incorporates a fire involving a patient's mattress and bedding with automatic sprinkler protection in a room suitable for two patients. No door was used, simulating the open door situation. A plastic trash container containing a prescribed amount of waste paper is located next to the bed. The newspapers are ignited

with a match and the trash container fire spreads to the bedding. Times are measured from time of ignition of trash in the container.

Instrumentation in this series measures:

- o Gas and surface temperatures at various horizontal and vertical locations in the burn room, doorway and corridor.
- o Total heat flux levels at the adjacent patient level (bed height), and accross the corridor from the burn room doorway.
- o Smoke obscuration at various heights in the doorway, corridor and lobby.
- o Gas velocity at various heights in the doorway and in corridor.
- o Gas anlaysis (CO, CO_2, O_2) in the burn room and doorway and CO in the lobby.
- o Weight loss (burning rate) of the mattress and bedding.

One wet automatic sprinkler head used for extinguishment is located in the center of the room. Three dry "tell tale" sprinklers pressurized by nitrogen are located nearby to provide data on response times of other types of sprinklers. In addition, smoke and heat detectors are located at the burn room center and in the corridor, 15 ft (4.6 m) east and west of the burn room doorway which faces north. Design features being addressed are: mattress type, combustible wall finishes, privacy curtains between bed and sprinkler head, sprinkler flow densities (average flow per unit floor area), nozzle pressures, and patient room ventilation.

The following table summarizes facility arrangements for the tests which have been completed:

BURNING ITEM*	WALL	PRIVACY CURTAIN	SPRINKLER	FLOW (gal/min)	VENTILATED
MO-3	FS-200	No	165°F-1/2 in SSP (73.9°C-.013m)	27 (102. L/min)	No
MO-2	FS-200	Solid	" "	" "	No
MO-2	FS-200	Meshed Top	" "	" "	No
MO-2	FS-200	No	" "	" "	No
MO-2	FS-200	Solid w/Steel hangers	" "	" "	No
MO-2	FS-200	No	" "	" "	Yes
MO-2	FS-200	No	160°F-3/8 in SSP (71.1°C-.01 m)	17 (64.4 L/min)	No

*

Coded according to previous mattress test series.

SSP - Standard Sprinkler Pendant, Ref-Underwriters Laboratory Standard #199, Automatic Sprinklers for Fire Protection Service.

MO-3 - Cotton innerspring mattress, cotton, felt padding, vinyl ticking.

MO-2 - Unretarded polyurethane padded innerspring mattress, PVC ticking.

FS-200 - 4 mm (5/32 in) in prefinished Lauan plywood; nominal flame spread classification 200 (Class C).

Preliminary analysis of the results based on seven full-scale tests indicates the following:

1. Fire involving the "MO-3" cotton mattress did not activate the automatic 165° sprinkler. A "tell-tale" quick operating 135° sprinkler did activate.

   Fire involving the "MO-2" polyurethane mattress always activated the 165° automatic sprinkler and the tell-tale 135° sprinklers.

2. The presence of the privacy curtain interfered with the normal sprinkler spray distribution. The overall cooling effect of the spray, however, controlled the fires and the combustible wall finish did not become involved in any of the fires.

3. Directional velocity measurements in the doorway indicated an almost complete reversal of gas flow after sprinkler operation when compared to pre-sprinkler conditions. Generally the result was that smoke and gaseous combustion products accumulating in the upper portions of the corridor outside the burn room were drawn back into the room, cooled and pushed out at the bottom into the corridor.

4. In all tests, after sprinkler operation, the carbon monoxide (CO) level increased. The greatest increase occurred with the presence of the privacy curtain and the polyurethane mattress as the burning item. The maximum level measured in any test was 5400 parts per million (.54%), at the bottom of the burn room doorway. CO levels in the lobby reached a maximum 1800 ppm (.18%). At these levels, it is estimated that a critical tenability level would be reached in the room 20 to 25 minutes after ignition. Critical tenability level is the time from ignition when incipient incapacitation occurs due to cumulative exposure to CO.

5. In all tests, the smoke level in the corridor lowered to approximately 4 ft from the corridor floor just prior to automatic sprinkler operation. One minute after sprinkler operation there was nearly total obscuration ($>$.9 optical density/m) from floor to ceiling throughout the test area, including corridor and lobby.

6. The incorporation of exhaust ventilation in the patient room (2 air changes/hour) did not influence sprinkler operation time. Ceiling temperatures, and combustion gases were slightly lower (-40°C and -.07% respectively) for the duration of the test than for the corresponding unventilated fire test.

7. The 27 gal./min. (102. L/min.) water flow corresponded to a sprinkler flow density of .17 gal./min. $ft.^2$ (6.9 L/min. m^2) which is the minimum flow from a single sprinkler for a system designed in accordance with NFPA 13. The .1 gal/min. $ft.^2$ (4.1 L/min. m^2) density (17 gal./min.) corresponds to all sprinklers operating in the design area, i.e. one sprinkler in the room plus two in an adjoining area. The test incorporating the 3/8 in (.01 m) orifice sprinkler flowing 17 gal./min. (64 L/min.) resulted in fire control and extinguishment equivalent to the ½ in. (.013 m) orifice sprinkler flowing 27 gal./min. (102 L/min.).

8. The corridor ceiling temperature did not reach a point in any test where a sprinkler, with the same thermal response properties as the sprinkler in the room, would have operated.

The next phase of this test series will include:

a. Fires involving patient room lockers.

b. Reduced water flow density with varying orifice pressures using ½ in. (.013 m) and smaller sprinklers.

c. Sprinklers positioned only in the corridor, with fires originating in the burn room.

II. Sprinkler/Spray Methods of Protecting Stairways

This project is being sponsored in part by the Occupational Safety and Health Administration, Department of Labor. The test facility is in the final phases of construction and preparation. It consists of a 3½ story stairwell with a burn room adjacent to one side of the stairway at the lowest level.

A state-of-the-art report is being prepared on the use of sprinklers and combination sprinkler/vent method for protecting vertical and horizontal openings. The report will include current code requirements and a description of the stairway test facility.

A tentative test plan has been established and is summarized as follows:

Objective: To develop parameters for alternative engineering designs for protection of open or partially open stairways by incorporating sprinkler or sprinkler/vent methods.

Instrumentation: Thermocouples will be installed in the facility to measure temperatures in the burn room and at all levels of the stairway. Velocity probes will measure airflow into the burn room and at the exhaust vent at the top of the stairway. Static pressure differentials will be measured between:

a. Burn room and base of stairs.

b. Base of stair and 1st floor stair.

c. Top of burn room and 1st floor stair.

Oxygen measurements will be made in the burn room, the 1st floor stair and at a vent at the top of the stairway. Radiant heat energy will be measured in

the burn room at the base of the stairs. Relative humidity will be measured at the stairway 1st floor.

Sprinkler System Protection Schemes

Two basic schemes will be used to determine the parameters for system design. The first involves a water curtain generated by standard pendent sprinklers between the burn room and the base of the stairs. The second involves conical spray nozzles combined with curtain boards* at the top of the stair at the 1st floor level.

Heat Source: A large propane burner will be located in the burn room. The flow rate of the burner is variable with a maximum heating rate of 1500 kW (5 million Btu/hr).

Test Procedure: For each sprinkler system scheme, tests will be conducted using at least three different energy release rates. At each level, sprinkler flows and nozzle pressures will be varied to determine parameters which will most effectively reduce the radiative and convective heat flow into the open stairway. Tenability levels for temperature, relative humidity, radiant heat flux and percent of combustion products will be considered. With the 2nd sprinkler protection scheme the depth of draft boards will be varied as a design consideration. The instrumentation will determine the variation in heat transfer, and pressure differentials created as a function of the heat output from the burner and the sprinkler and spray nozzle arrangements. From these data engineering design parameters can be established to include sprinkler nozzle types and orientation, nozzle pressure, flow density, depths of curtain boards and capacity and orientation of air handling equipment.

* A curtain board is a rigid noncombustible screen hung from a ceiling to block convective heat flow across a ceiling.

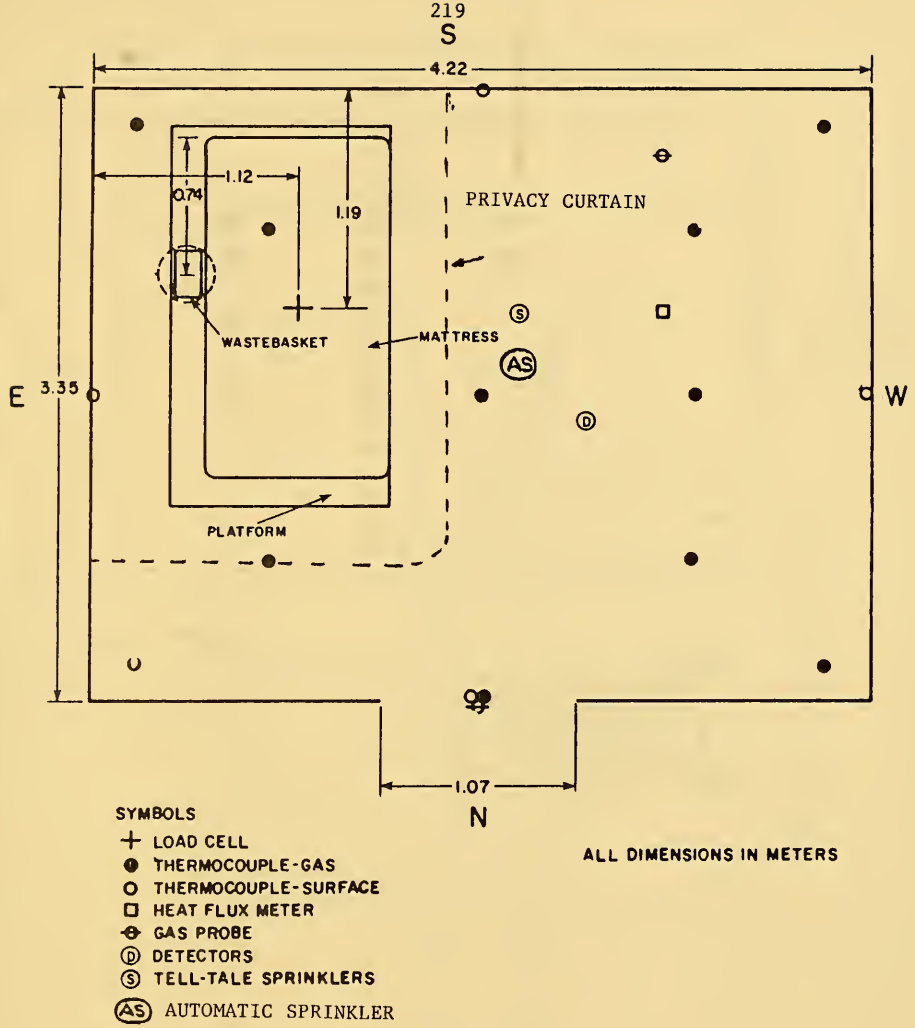
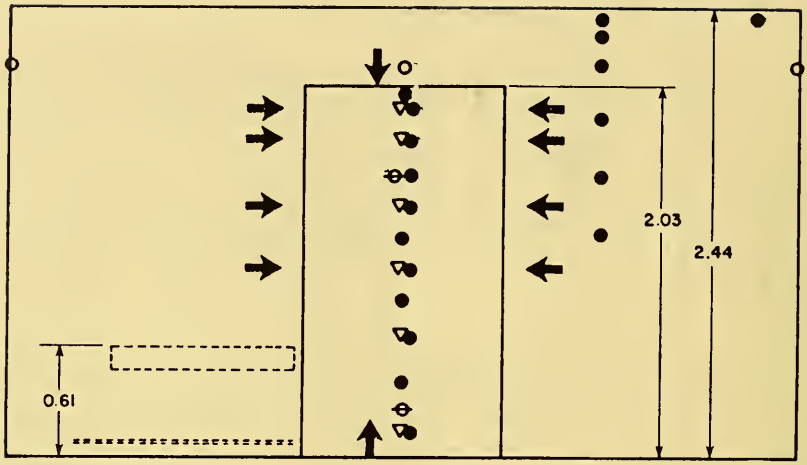


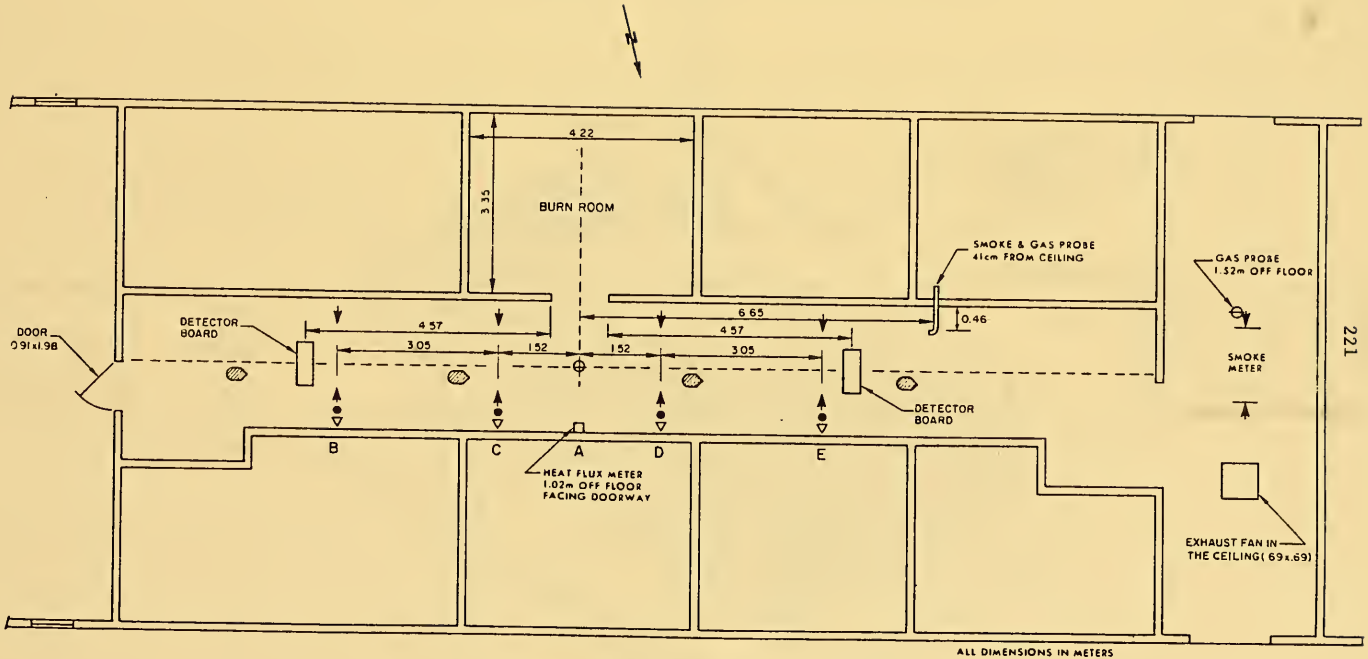
FIGURE 1. BURN ROOM PLAN VIEW



ALL DIMENSIONS IN METERS

SYMBOLS
- ● THERMOCOUPLE-GAS
- ○ THERMOCOUPLE-SURFACE
- □ HEAT FLUX METER
- ▽ VELOCITY PROBE
- ⟵ SMOKE METER LIGHT PATH

FIGURE 2. BURN ROOM - DOORWAY ELEVATION



CORRIDOR/LOBBY INSTRUMENT STATIONS
floor plan

SYMBOLS:
- ● THERMOCOUPLE-GAS
- ▽ VELOCITY PROBE
- ◄ SMOKE METER LIGHT PATH
- ⊖ GAS PROBE
- □ HEAT FLUX METER
- ▨ COLUMNS

FIGURE 3. CORRIDOR/LOBBY INSTRUMENT STATIONS - FLOOR PLAN

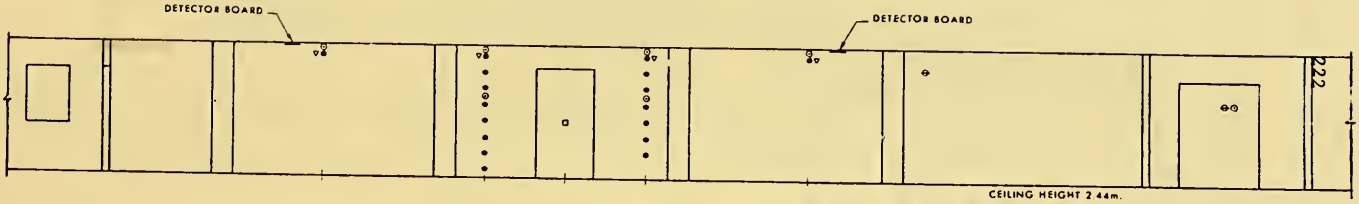


FIGURE 4. CORRIDOR/LOBBY INSTRUMENT STATIONS - ELEVATION

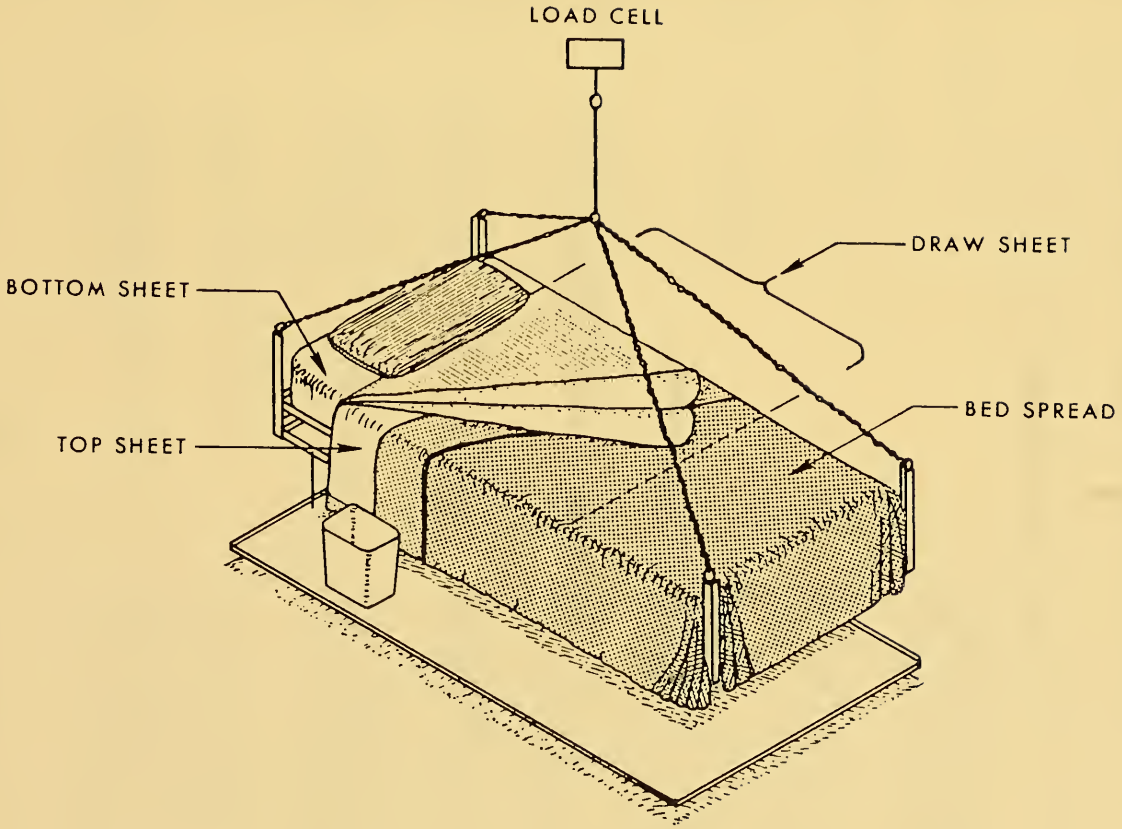


FIGURE 5. LOAD CELL SUSPENSION FOR MATTRESS & BEDDING

APPENDIX

Final Agenda

&

Conference Invitees/Attendees

FINAL AGENDA

NATIONAL FIRE PREVENTION AND CONTROL ADMINISTRATION
NATIONAL BUREAU OF STANDARDS/CENTER FOR FIRE RESEARCH

CONFERENCE ON LOW-COST RESIDENTIAL SPRINKLERS

TUESDAY, NOVEMBER 29, 1977

APPLIED PHYSICS LABORATORY
THE JOHNS HOPKINS UNIVERSITY
HOWARD COUNTY, MARYLAND

9:00 a.m.	Welcome	Dr. Walter G. Berl Group Supervisor Applied Physics Laboratory The Johns Hopkins University
9:05 a.m.	Opening Remarks	Dr. Joseph E. Clark Associate Administrator for Fire Safety & Research National Fire Prevention & Control Administration
9:10 a.m.	The NFPCA Low-Cost Automatic Residential Sprinkler Program. Purpose-Program-Future	Harry Shaw Director, Technology Development National Fire Prevention & Control Administration
9:35 a.m.	"Study to Establish the Existing Automatic Fire Suppression Technology for Use in Residential Occupancies" Findings-Conclusions	Rolf Jensen President Rolf Jensen & Associates
10:00 a.m.	"Assessment of the Potential Impact of Fire Protection Systems on Actual Fire Incidents". Findings-Conclusions	Byron M. Halpin Applied Physics Laboratory The Johns Hopkins University
10:30 a.m.	COFFEE BREAK	
11:00 a.m.	"Low-Cost Residential Sprinkler Systems". Findings-Conclusions	Dr. Hsiang-cheng Kung Principal Investigator Factory Mutual Research Corp.
11:30 a.m.	"Experimental Investigation of Low-Cost Sprinkler Systems Concepts". Findings-Conclusions	Norman Henderson Principal Investigator Battelle Columbus Laboratories

12:00 noon	LUNCH	
1:15 p.m.	The Plan to Modify Sprinkler Standard NFPA 13-D	Chester Schirmer President Schirmer Engineering Corp. (Chairman of NFPA 13)
1:30 p.m.	Performance Specification "Low-Cost Residential Sprinkler Systems"	Graham Clarke Principal Investigator Factory Mutual Research Corp.
3:00 p.m.	COFFEE BREAK	
3:30 p.m.	Performance Specification "Low-Cost Residential Sprinkler Systems"	Graham Clarke Principal Investigator Factory Mutual Research Corp.
5:30 p.m.	Closing Remarks	Harry Shaw Director, Technology Development National Fire Prevention & Control Administration
6:30 p.m.	DINNER	APL Dining Room
7:45 p.m.	The Automatic Fire Sprinkler is an Answer to the Fire Problem	Byron Chaney Fire Chief Palm Springs, California

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WEDNESDAY, NOVEMBER 30, 1977

NATIONAL BUREAU OF STANDARDS
CENTER FOR FIRE RESEARCH
GAITHERSBURG, MARYLAND

9:00 a.m.	Welcome	Richard Custer Chief, Program for Fire Detection & Control Systems National Bureau of Standards Center for Fire Research
9:15 a.m.	A Case for Sprinkler Protection	Richard Patton President Patton, Incorporated
9:30 a.m.	NBS/CFR Sprinkler Programs	John L. O'Neill Fire Protection Engineer National Bureau of Standards Center for Fire Research
10:30 a.m.	COFFEE BREAK	
10:45 a.m.	Tour of NBS/CFR Facility	
12:30 p.m.	ADJOURNMENT	

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